Office of Naval Research
European Office
93-07

NAVSO P-3678

ESN

INFORMATION

BULLETIN

European Science Notes Information Bulletin
Reports on Current
European and Middle Eastern Science

In this issue, reports on...

Computer Science	Oceanography
Materials	Policy

Special focus...

- Coastal Ocean Forecasting Systems in Europe—Part 2 - 433

OFFICE OF NAVAL RESEARCH EUROPEAN OFFICE

The mission of the Office of Naval Research European Office (ONR Europe) is to assist the Chief of Naval Research, the Chief of Naval Operations, and the Commandant of the Marine Corps in discharging their responsibilities on matters of general scientific and technical interest to the U.S. Navy in the United Kingdom, Europe, and the Middle East.

To carry out this mission, ONR Europe:

- Maintains liaison with European and other designated government, academic, and industrial agencies conducting research and development (R&D) of naval interest
- Assists U.S. Navy agencies in monitoring specific R&D projects
- Assists U.S. Navy personnel in mutual technology exchange under negotiated agreements
- Disseminates to the U.S. Navy R&D community matters of scientific and technical interest

---

ORGANIZATIONAL INDEX

Telephone: 44-71-514 + ext.

Office of the Commanding Officer and Scientific Director

Code	Ext.		
00	4417	Commanding Officer	CAPT John M. Evans
01	4508	Scientific Director	Dr. Arthur M. Diness

Liaison Officers and Liaison Scientists

13	4131	Computer Science	Dr. Lawrence J. Rosenblum
16	4260	Electronics	Dr. Nicholas Bottka
19A	4413	Naval Air Technology	CDR Dale A. Milton
21	4260	Environmental Systems Technology	LCDR David B. St. Pierre

U.S. Mail Address
PSC 802 Box 39
FPO AE 09499-0700

U.K. Address
223/231 Old Marylebone Road
London NW1 5TH

TELEX: (900) 7402119 ONRE UC
OMNET: ONR.EUROPE

FAX: 44-71-724-7030; 44-71-723-1837
MILNET: ONREUR.NAVY.MIL

ESN INFORMATION BULLETIN

This publication is an official publication of the Office of Naval Research European Office. It describes research that is being conducted in Europe and the Middle East.

Commanding Officer ..... CAPT John M. Evans, USN
Scientific Director ..... Dr. Arthur M. Diness
Editor ..... Ms. Maureen L. Long

93-07

In This Issue. . .

Coastal Ocean Forecasting Systems in Europe—Part 2

by John P. Dugan. Dr. Dugan was the Liaison Scientist for Physical Oceanography for the Office of Naval Research European Office. Previously he formed and directed the Field Measurements Department for Areté Associates. Earlier, he was at the Naval Research Laboratory, Washington, D.C. He has returned to Areté Associates.

KEYWORDS: coastal oceanography; shelf edge models; physical oceanography; interdisciplinary modeling; transport processes

INTRODUCTION

This study has assessed operations and research associated with coastal ocean forecasting systems that are operated by the countries surrounding the North Sea. These systems have been designed and constructed to provide timely predictions on water level, currents, waves, and other water parameters. They originally were developed to provide advance warning of severe flooding by North Sea surges. Their capabilities are now being vastly expanded because of the many additional requirements of modern society. The countries have significant experience in operating these systems. The research and developmental work, although not specifically more advanced than similar basic research activities in the United States, certainly is very strong.

To meet these largely nonmilitary needs, a variety of coastal monitoring and prediction systems are in place and are used by nations and local authorities that have extensive coastlines in western Europe. The more extensive operational ocean forecasting systems to date have been modest add-ons to national meteorological forecasting offices. However, a significant amount of research and development of new systems is more often found in university and government laboratories.

The U.S. Navy requires environmental information for predicting the operability and performance of present and future systems. The state of the ocean and weather often have an overriding influence on the performance of surveillance and weapons systems and, therefore, have an influence on the tactical deployment and operation of assets that are available to a theater commander. Thus, there is an obvious need for environmental systems that can provide tactical guidance to the fleet concerning the performance of deployed Navy systems. There is a comparable need for providing guidance in the development process for new systems that are expected to be affected by the environment. In the latter case, our environmental knowledge must provide predictions of the performance of a given surveillance or weapons system early in the development cycle.

Part 1 of this study (*ESNIB* **93-06**) provides the Background and U.S. Navy Interest in these European systems; it contains an extensive Summary of our findings and makes Recommendations. Part 1 also includes descriptions of European Community (EC) and United Kingdom (U.K.) efforts. Part 2 describes efforts underway in The Netherlands, Norway, Denmark, the Federal Republic of Germany, Belgium, and France.

THE NETHERLANDS

INTRODUCTION

Operational models for water motions in the vicinity of the Dutch coast are a joint responsibility of the Royal Netherlands Meteorological Institute (KNMI) and the Rijkswaterstaat (RWS). The RWS has numerous divisions; we focus here on the Tidal Waters Division, which performs the research and development of models, and the North Sea Division, which is more involved in running the models and providing the forecasts, particularly for the Dutch coastal and offshore region. The RWS has additional divisions that focus on other regions. It also includes institutes (such as Delft Hydraulics and the Technical University of Delft) that perform considerable research and development on models for engineering-related activities. These activities include modeling sediment transport and simulating hydrodynamic forces on various construction designs. The work of KNMI and the two divisions of

RWS mentioned above are assessed in detail here. A short description of work at Delft Hydraulics also is provided, although more details on the programs at Delft are available in a recent *ESNIB* article.[1] Finally, a short discussion of research at the Netherlands Institute for Sea Research (NIOZ) also is provided.

ROYAL DUTCH METEOROLOGICAL INSTITUTE

The Royal Dutch Meteorological Institute (KNMI, for Koninklijk Nederlands Meteorologisch Instituut) is The Netherlands agency responsible for weather forecasting. Because of their operational experience, capability, and ready access to real-time meteorological data and models, KNMI is also responsible for running operational models for predicting ocean conditions in the North Sea. The third-generation wave prediction model (WAM 3) is run for the North and Norwegian Seas, while a two-dimensional (2-D) barotropic circulation model is run for tide-surge predictions. In addition, research is performed within the Physical Oceanography Research Department of KNMI to improve the performance of both models, by improving the physics of the approximations as well as by upgrading the implementation in the operational system.

KNMI is an institute in the Ministry of Transport, Public Works and Water Management, and is a sister institute to the Rijkswaterstaat (RWS) that is specifically responsible for water-related matters. KNMI has three major directorates:

- The Operations Directorate is responsible for weather forecasts for the general public as well as for specialized customers such as shipping, aviation, agriculture, and vehicular traffic. It also provides archived data on weather and climate to users and researchers.
- The Research Directorate carries out research in the fields of dynamical and physical meteorology, physical oceanography, and seismology. The Director of the Physical Oceanography Research Department in this Directorate is Dr. Gerbrand J. Komen, who is widely known for his activities in the international program called WAM on the development of ocean wave forecasting models. For improvement of the forecasting activities, there are projects in the development of new models. Current examples exclude those for wave forecasting and atmospheric transport of pollutants. Research is performed in the general discipline of dynamic meteorology but also specifically in those processes important in determining the climate. Studies of boundary layer dynamics assist in the formulation of improved boundary conditions for both atmospheric and ocean forecast models.
- The Technology and Information Directorate supports the other parts of the Institute with instrumentation, computer facilities, and software support.

To further support its activities, KNMI is an active member of several very large international organizations, including the World Meteorological Organization (WMO), the European Centre for Medium-Range Weather Forecasts (ECMWF), and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). KNMI engages in exchange of scientists on visiting appointments for various periods of time to and from these organizations as well as other research organizations.

Of the approximately 530 full-time KNMI employees, about 250 are in operations, 80 in research, 120 in technology, and 80 in management and general services. Almost 80% of the staff are at the main site in De Bilt, which is a suburb of Utrecht. The remainder are scattered about the country at smaller operations offices, the largest being at airports.

NEDWAM, the Operational Wave Forecasting Model

The model called NEDWAM (for NEDerlands WAve Model, often locally called Dutch WAM) is used operationally to forecast the surface wave

field in the North Sea and southern part of the Norwegian Sea.[2] It has been operational in a previous form called GONO (GOlven NOordzee) for some years. The physics in the present model are identical to those in the global wave model WAM 3 (for the third-generation WAve Model). It simply is a North Sea version of the global WAM that has been implemented and runs operationally on the computer at the European Centre for Medium-Range Weather Forecasts (ECMWF). It includes the latest developments of the international group of wave modelers that have been deeply involved in the WAM program. This group includes the leading scientists, Drs. Gerbrand Komen and Peter Janssen of KNMI; the latter has been involved in WAM implementation at both KNMI and ECMWF.

NEDWAM models the evolution of the 2-D surface wave variance spectrum at all spatial points in a stereographic grid that covers all of the North Sea and a large part of the Norwegian Sea. There are a total of 612 grid points with a spacing of approximately 75 km; the spectrum is represented at each of these grid points by 300 wave vector elements at 25 discrete frequencies and 12 directions. The model uses a 30-minute time step for the propagation of the spectral components and a 15-minute step for the generation and decay components. The forecast period is 30 hours, and it includes an analysis period of either 6 or 12 hours to improve the wave estimates from the previous operational run of the model.

The fundamental (and very time-consuming) calculation in the model is a numerical solution of the energy balance equation for the waves: They are propagated in the appropriate direction at their appropriate group speed; they are generated by a wind source term; they decay by dissipation sink terms (both for wave breaking and bottom friction); and they interact nonlinearly, all through parametric expressions that are specified by the WAM formulation. The primary external input that generates the waves is the vector surface wind stress, and this is supplied from the meteorological forecast model. The wind is taken to be the 10-m wind from the ECMWF Fine Mesh Limited Area atmospheric circulation Model (LAM). If this is not available, it is taken from the United Kingdom (U.K.) Meteorological Office LAM data field, both of which are available to KNMI.

Actually, the wind stress is required, and the value of the local stress is calculated as a parametric function of the 10-m wind speed and the air-sea temperature difference that are obtained from either of the meteorological forecast models. The exact parametric formulation for the stress is a matter of current research. The present formulation uses a prescription published by Janssen and Komen a few years ago, and it includes buoyancy and wind speed effects. However, it suffers several known problems, such as a sub-optimal implementation of wave age and nonalignment of wind and wave directions. Drs. Janssen and Vladimir Makin are deeply involved in attempts to improve this aspect of the model. More details on the formulation of NEDWAM are provided in Ref. 2, which can be obtained by contacting any of the KNMI scientists at the mailing or e-mail address provided at the end of this article.

The model puts out a prodigious amount of data, so summaries of the spectrum such as significant wave height, the direction of the dominent swell and wind waves, and the period of the spectral peak provide a summary of the information in the spectrum. These are distributed and studied in the form of contour plots.

The primary purpose of the model is to forecast the wave spectrum in the North Sea, but the southern Norwegian Sea is included because significant low-frequency swell actually enters the North Sea from the northwest. Even then, very strong storms in the North Atlantic can generate very-low-frequency swell that is not adequately accounted for in the model. Also, the grid spacing is rather large to properly model the English Channel, so the model is considerably less accurate for low-frequency waves in the vicinity of the Dutch coast in the case of strong winds from the southwest. Typical accuracy is 0.5-0.7 m for significant wave height and about 1 s for the significant wave period.

These problems could be alleviated by several improvements in the methodology. One way would be to improve the formulation of the wave spectrum at the western edge of the grid, either by using the ECMWF WAM results or by making an extended area run at KNMI. The possibility of using the WAM data output as well as Norwegian wave model results is being researched at present. Another way would be to assimilate data on the

swell content of the spectrum from other observations. The swell observations are considered much more important than wind wave observations because the latter are so much more dependent on the accuracy of the wind observations and/or analyses. There is a significant research effort on data assimilation, with data from wave buoys, offshore platforms, and the ERS-1 altimeter.

The use of satellite data makes a lot of sense in the case of the global WAM that is run at ECMWF; more information on intra-European programs are provided in Part 1 of this report. In the case of NEDWAM, this is implemented in a semi-operational model called DA NEDWAM (for Data Assimilation NEDerlands WAve Model, of course), and it uses the scatterometer data from ERS-1. Drs. Komin, Vladimir Makin, and Gerrit Burgers are researching the assimilation of wave observations. Data from about 10 platforms and buoys in the Dutch North Sea Network and the ERS-1 altimeter are used to update the wave heights and periods by optimal interpolation.[3] Errors in the analysis are reduced dramatically to less than 0.2 cm in significant wave height, but the period is changed only marginally in verifications performed to date. Research is ongoing.

Also, the wave age dependence of the stress apparently could be improved by iterating the calculation at each time step for the local predictions. However, the effect of buoyancy is also a problem, and this cannot be solved so easily. The difficulty here is that predictions of surface temperature by the meteorological forecast models are not very good (and this, in turn, actually negatively affects the wind speed predictions of the meteorological model). Because of the inaccuracy, the meteorological models typically use climatic surface temperatures for their runs. Thus, significant improvements in estimates of surface stress will require better surface temperature estimates. The only improvement in the meteorological model on the horizon, so to speak, is an improvement in the spatial resolution with the introduction of a HIgh Resolution LAM, or HIRLAM. This doubles the resolution of the meteorological model, and it is being evaluated.

Dr. Luigi Cavalieri of the Instituto per lo Studio della Dinamica delle Grandi Masse, Consiglio Nazionale delle Richerche (National Research Council, or CNR) in Venezia, Italy, is a colleague in the WAM group. He is well-known for his activities as the "engineer" who has kept the group focused on practical applications, particularly satellite applications. He was instrumental in implementing the VENICE model for shallow-water wave propagation. Dr. Cavalieri, the Hasselmanns (of the Max-Plank-Institute in Hamburg), Janssen, Donelan, and Komen are doing their final editing of their respective chapters of a book on wave models. This book, *Dynamics and Modeling of Ocean Waves*, is an update of the previous WAM publication, *Ocean Wave Modeling, the SWAMP Group*. However, it is much more detailed and has a much improved section on the applications; it should find an audience of avid readers.

Storm Surge Model

Dr. Hans de Vries implemented the operational surge model at KNMI, and he is responsible for its continuing operation and maintenance. It was developed as a coordinated effort of the Tidal Waters Division of the Rijkswaterstaat (RWS), Delft Hydraulics, and KNMI. It is operated by KNMI because of the necessary close connection with the meteorological forecasts. The output of the surge model is sent by KNMI to the Storm Surge Warning Service (SVSD) that is operated by RWS (more on this organization in a later section of this article) in The Hague. Their responsibility, in turn, is to react to any developing dangerous situations by notifying the appropriate authorities. Necessary actions are then made to warn the public and to close several very large storm surge barriers.

The model for the prediction of water level in the North Sea is called WAQUA. The current version is called WAQUA/CSM-16, for the 16-km resolution of the grid spacing. WAQUA was originally developed as a cooperative effort between the RAND Corporation and RWS, and it has been modified and updated several times. The model solves the nonlinear, 2-D, depth-integrated equations of motion with a quadratic bottom drag formulation with constant Chezy coefficient and a Janssen modified Smith-Banke quadratic wind stress formulation. As before, the wind is forecast from the 10-m level of the LAM meteorological forecast. The equations are solved in spherical coordinates by an ADI (Alternating Direction Implicit) method on a staggered C-grid with depths

at the centers of the grid boxes. The advection scheme is central but changed to upstream at coastlines. The grid covers the whole northwestern European continental shelf. The outer boundary is a straight line beyond the shelf edge, at the 200-m or deeper depth contour. The tidal forcing (originally provided by Flather at Proudman Laboratory in the U.K.) and the Chezy coefficient have been subject to modest tuning to provide accurate results, i.e., agreement of forecast water level with measurements of the tide stations in the absence of significant weather forcing. However, as is seen below, this is not of overiding importance because of the way in which the final estimate of water level is made.

For the forecast, the model actually is run both with and without the surface forcing. The difference between the two runs is calculated, and this is added to archived tidal information from RWS that is based on harmonic analysis of historical tide data. Thus, errors in the astronautical tides are minimized. This is an unusual technique, but they feel it is most accurate for the high tides that they experience along the Dutch coast.

Although the WAQUA model can handle drying out and flooding of the shallow parts of the estuaries, this is not enabled in the operational system to maximize vectorization of the code in the CSM-16 model. This is accurate enough for most of the coastal region, but it fails in the Waddenzee where this effect is significant. The water level in this area is forecast as a linear combination of the wind stress and the forecast level outside the area.

The actual forecast run is made four times per day following the most recent LAM run. The wind and pressure are bilinearly interpolated in space and linearly in time to those space-time points required in the run. The WAQUA forecast actually runs from an analysis from the beginning of the previous forecast until the start of the current forecast with the new analyzed wind and pressure fields. The actual run time is 2 minutes on their Convex 220. The output is a time series of water levels at many points of interest along the coast and estuaries, and these are transmitted to the many users of these data. The data are archived along with times and levels of the high and low water for post analyses of the accuracies that are achieved.

Dr. Janet Onvlee has performed an analysis of the effect of the wind stress formulation on the surge forecast. An accurate parameterization of the momentum flux on the bulk properties of the atmosphere and ocean is important for many areas of air-sea interaction research, and it remains an area of contention. It is clear, for example, that stress cannot be accurately estimated as a function of wind speed alone; it also must depend on other parameters such as the state of the surface waves and the air-sea temperature difference. Dr. Peter Janssen of KNMI, who presently is at ECMWF, actively works in this area. To account for wave age in the stress, there would have to be an interaction between the surge and the wave models. This interaction is still only being discussed at present, and wind speed remains the only parameter in the model.

Dr. Onvlee has compared hindcasts and forecasts for many storms using the Smith and Banke formula, the Charnock (with $\beta = 0.031$) formula, and a formula suggested by RWS (another piecewise continuous function) for the stress formulation. The results are complex, but the resulting rms errors in level are about 15 cm or less rms for all tide stations. Both the RWS and Charnock formulae provide maximum water levels that are significantly closer to the observations, especially for the higher surges. The difference between the two better formulae is less than 2 cm, but the RWS formula provides a smaller rms error of the peak levels. Since the primary use of the model is to predict the maximum surge levels, either of these are considered adequate for the requirement. The RWS relation actually has been used in the model since 1991, and this analysis (in retrospect) confirms it to be the appropriate choice.

Several research models are being evaluated. The stress formulation of Janssen is being tested. In this model, the value of the local stress is estimated as before, the waves are calculated, and then the stress is iterated to account for the dependence on the wave age. Dr. Janssen also is working on this aspect of the model during his 2-year appointment at ECMWF. In addition, the group is researching the possibility of using the air-sea temperature difference, but they have no results to report to date. Finally, the group is involved in research with RWS in using a data assimilation

scheme to utilize the tide station observations to improve the accuracy of the model. Presently this involves the use of a Kalman filter with constant gain matrix. Preliminary results provide improved forecasts out to about 12 hours, with reduction in rms level errors to less than 10 cm, but they deteriorate to worse than the case with no assimilation after 12 hours. Reference 4 provides a recent discussion and review of a research variant of the Dutch operational tide surge model.

Finally, this group is interested in extending the model to 3-D. They consider the best model of their region of interest to be one developed previously by Dr. Backhaus from the Institut fur Meereskunde in Hamburg.

Research on Boundary Layers

Dr. Peter A.C.M. Janssen presently is on leave from his position as head of the air-sea interactions group and is at ECMWF. He continues to perform research on the dynamics of the boundary layer near the ocean's surface. The focus of his work has been on the physical parameterizations that go into the wave models. He is and has been working on the interaction of the wave and circulation models to improve the accuracy of both. His primary focus has been on the dynamical coupling of a wave model and a circulation model through the atmospheric boundary layer.[5] Briefly, it involves the introduction of a wave-dependent drag coefficient for the wind stress that is required in both models.

Dr. Vladimir Makin (originally from the St. Petersburg Branch of the Shirshov Institute of Oceanology) leads the boundary layer research in the absence of Dr. Janssen. He is pursuing the use of a 1-D turbulence model of the atmospheric boundary layer above the wave surface to provide an improved estimate for the wave growth due to the wind. It includes a novel aspect of the wind being at arbitrary angle to the waves.[6] Like all theoretical models of energy input from the wind, the results are small compared with previous measurements, and the dissipation must be tuned downward in magnitude to account for this difference.

Instrumentation

The Research Department engages in work related to the physics and accuracy of the approximations in the models, as discussed above, but it also engages in research and development associated with measurement tools. Dr. Wiebe Oost in the Physical Oceanography Group, in particular, has been active for many years in the development of new instrumentation for making observations at sea. He has significant results from his central part in HEXMAX (the HEXOS MAin Experiment), including a contribution to the wave roughness-stress relationship.[7] He is also well known for his many publications on his development of a pressure anemometer for measuring the 3-D velocity field from platforms at sea. This method uses the differential pressure developed by the wind blowing around a sensor head. It is very rugged and not susceptible to breaking by wave slap or to contamination by particulates in the marine atmosphere as are other methods. This solved a previous problem of high-frequency instruments that were susceptible to salt spray. His recent innovations have extended the capability of the instrument to wind speeds as low as 2 m/s.

Dr. Oost now is working on a new technique for making direct measurements of the flux of CO_2 at sea. Although this is most directly of interest to climatic research, it is interesting in the context of naval oceanography because the flux of CO_2 is directly associated with fluxes of other gases across the surface. The total transport, of course, is dependent on the relative concentrations of CO_2, but the processes at the surface are the same as with other gases that are dissolved in the water and overlying atmosphere. This method uses the absorption of infrared (IR) radiation by CO_2 in the air in an active infrared beam that is transmitted across a short aperture. Water vapor also absorbs some of the radiation, and this is accounted for by simultaneous measurement of water vapor by a Lyman α water vapor sensor. The flux of CO_2 then is calculated by using a nearby velocity sensor and applying the eddy correlation technique. This general technique for calculating the CO_2 flux is not unique, but he is improving it by using liquid nitrogen to cool the IR receiver to reduce the level of noise that has previously limited the dynamic range of the technique. The high noise level had previously limited the technique to high flux events, so that the more typical low flux cases could not be examined. The new instrument is expected to be deployed for the first time in the

Air Sea Gas Exchange Experiment (ASGASEX). This experiment will be performed on the Rijkswaterstaat research platform, 9 km off the coast near the Hoek van Holland, which is planned for September 1993. This experiment also is of interest to us because it will involve a number of researchers who are trying to understand momentum, heat, gas, and particulate fluxes at the ocean surface.

Discussion on KNMI

This small research group is actively involved in work to improve these models and their predictions. The research will continue to be among the best in the world in the areas mentioned because of the abilities of Komen, Janssen, Oost, and others. However, there is an organizational problem on the horizon. The institutes in the Ministry of Transport, including KNMI but excepting RWS, are expected to be privatized in the near future. This is expected to force these institutes to move closer to their specific customers, but this is a problem for meteorological institutes. It is a problem that in fact is shared with others in western Europe. For example, a similar situation faces the Meteorological Office in the U.K. The fundamental issue is the smooth transition from what (to the present time) has been thought to be the responsibility of a government agency to that of an independent agency. It includes difficult questions such as how to recover the operating costs. For the specific case of these oceanographic applications, the difficulty is expected to be no more straightforward than for weather forecasts. In this case, RWS is the primary customer, but that organization is inextricably involved in the forecasting process as well. For example, RWS provides most of the fundamental oceanographic data as well as some of the offshore meteorological station data to KNMI for input to the forecasts. KNMI adds the value of all the other meteorological data that are available, runs the model, and distributes the results. But the value added, and the specific cost for this value added, clearly will be a matter for involved negotiations in the near future. The precise path for implementing this process of privatization seems a mystery to all involved at KNMI as well as at RWS.

RESEARCH AND OPERATIONS AT THE RIJKSWATERSTAAT (RWS)

RWS is the government agency in The Netherlands responsible for pursuing most water-related issues, including the construction and maintenance of flood defenses, flood warnings, dredging, shipping support, and water quality. The primary subject of this assessment is their work associated with the operational forecasting of ocean waves and water level. The operational models used were developed in conjunction with other agencies such as the Royal Netherlands Meteorological Institute (KNMI) discussed above, and the products very much remain a joint effort of the two agencies. The specific groups discussed in the following are

- the North Sea Directorate, which is responsible for supporting and distributing the ocean forecasts, and
- the Tidal Waters Directorate, which performs research and development for improving the forescasting systems.

This work is important to The Netherlands because their safety and economy depend more on their control of the sea than practically any other country in Europe, if not the world. The Dutch part of the North Sea has an area that is about 1.5 times larger than the Dutch mainland, yet the average depth is only about 40 m. Because of the extensive shallow-water zone, and the importance of Rotterdam especially as a shipping port for northern Europe (presently the largest tonnage port in the world), they maintain very long shipping channels by dredging. Other important economic activities include fishing and oil, gas, and sand extraction. For instance, to support the transport of the petroleum extracts, more than 1100 km of underwater pipelines have been constructed.

Overall Responsibilities and Structure

The RWS is under the Director-General for Public Works and Water Management in the Ministry of Transport, Public Works and Water Management, and the extended title pretty much sums

up the responsibilities. RWS is organized into 12 provinces associated with actual territory, and 5 directorates having non-territorial responsibilities. The headquarters of RWS is centrally located in Den Haag (The Hague). It is collocated with the Tidal Waters Directorate, which is responsible for most research and development activities.

The North Sea Directorate (Directie Noordzee), one of the regional directorates, is located in Rijswijk, a suburb of Den Haag. Its responsibility is the water in the Netherlands zone of the North Sea, whereas the other regional directorates are associated with districts that are onshore, estuarine, canals, or rivers. The North Sea Directorate has two primary technical divisions, the Technical and the Water System Management Divisions, the latter being associated with water quality. The two primary branches in the Technical Division support the shipping channels, including their dredging, and work associated with hydrographic surveying, and instrumentation. This latter branch is split into groups asociated with survey ships, work on fixed platforms, and instrumentation development.

The Technical Division undertakes many activities to support the operation of the ocean forecasting system, including the collection of data that goes into the forecasts and the distribution of warnings and advisories that result from the forecasts. These activities are centered at the Hydro Meteo Centre Rijnmond (HMR), which is located not far from Den Haag at Hoek van Holland where the Rhine enters the North Sea. This Center actually is located on sand dunes in a refurbished building that once was a World War II lookout station.

Observational System

The ocean observation system is called MEETNET NOORDZEE, and it is under the direction of Mr. Yap Starke. It is composed of a network of sensors and telemetry links that provide data from the instruments to HMR in real time. The observations include air presssure, wind speed and direction, air temperature, humidity, visibility, cloud height, weather, water height, and wave spectrum (directional in some cases). These sensors are being upgraded to include water temperature and will include other properties of water quality as sensors become available. The raw data are collected at up to 4 Hz, and then downsampled to either 10- or 20-minute period for transmission to the Center. The sensors are mounted on many different types of platforms, including oil production platforms, navigation towers, and buoys. They also include 150 water level gauges, including 5 tide gauges of the U.K. east coast system. Many wave buoys provide (unidirectional) spectral information. Presently several directional buoys are in the system, with more being implemented. The data are collected by a network of communication systems—some radio, some dedicated landline, and some telephone line. Much of the data are obtained from other authorities who communicate on a common network. This is necessary for obtaining data in real time to assist the forecasts, but it also is convenient for scientists to gain access to data archives, both for trouble shooting and for research.

Also in the Instrumentation group is work in support of the measurements made by the five vessels of the North Sea Directorate for their survey operations. This includes the common suite of instrumentation for water-quality measurements and for water depth. One of the ships, for example, is practically dedicated to measurements to support the maintenance of the Euro Channel into Rotterdam.

A convenient personal-computer-based system has been developed to remotely access both present and archived oceanographic and meteorological data in this system. Scientists and operators use common software packages to retrieve, display, and analyze the data for their analyses and verifications.

Finally, although not directly involved in data collection for the operational system, the North Sea Directorate also operates a Dornier 228-212 aircraft for routine supervisory and surveillance flights over the North Sea, harbors, and inland waters. The aircraft normally carries a sidelooking airborne radar, ultraviolet-infrared linescanner, infrared camera, and low-light-level camera.

Operational Systems

HMR performs real-time checks on the quality of the MEETNET data and the forecasts from KNMI, and issues warnings and advisories to the appropriate coastal authorities. There are several forms of these advisories:

- high water advisories are issued to safety authorities when an extraordinarily high water level is expected; this provides warning of coastal flooding conditions;,
- low water advisories are issued to navigation authorities to advise shipping of unsafe water levels in the dredged channels into Rotterdam and Amsterdam.

Rotterdam is the busiest port in the world; its channel is more than 60 km long and is dredged for ships having draft up to 74 ft.

Mr. Frits Draisma is in charge of the warning systems and Mr. Robert van Houten runs the Operations Floor at HMR. The warning procedures are reasonably straightforward, using the predictions for waves, wind, and water level that are produced and communicated to HMR by KNMI. For low water, the water level forecast is used with both the forecast of very-low-frequency waves and the characteristics of particular ships to provide a ship movement advisory for safe navigation of large ships in the dredged channels. The advisory and appropriate level of warning are prepared from a nomogram that includes the results of a many-year development program that ostensibly accounts for effects that could cause grounding and/or loss of control of large ships in the channels. The specific problem is low water in combination with high levels of very-low-frequency swell (20-25 s period). This combination occasionally approaches the Rotterdam channel from the northwest and has the potential to cause grounding. A specific advisory is prepared for each Very Large Crude Carrier (VLCC) that enters the Rotterdam channel.

HMR also operates an oil spill model (called Transpill) that was developed by RWS in cooperation with TNO in Delft. It uses the astronomical tidal currents and estimated wind drift, so it is not particularly complex.

Research and Development

The Tidal Water Directorate in Den Haag performs the R&D on forecasting models; Ir. Henk Keyser specializes in waves and Ir. Leo de Vrees in tide/surges. The primary need for further research on forecasting of waves is to provide better forecasts for harbor entrances and coastal defenses, both of which are in extremely shallow water. All the users, namely shipping, dredging, construction, and engineering works, have problems in shallow water, yet the models really do not provide appropriate data for deeper water offshore. Thus, the emphasis on the work by Ir. Keyser is to improve the extension of the forecasts into shallow water.

His group is part of a North European Storm Study and is constructing a 25-year climatology of waves on the coast from a data archive of waves in deeper water (20 m). They are using a propagation model (HISWA, a 2-D stationary wave model) in a hindcast mode to calculate wave statistics for storms at the breaker zone at many locations along the coast. This group also has been involved (with Datawell, the Oceanographic Company of the Netherlands, and the Technical University of Delft) in developing the very successful Wavec wave measuring buoy. Finally, they have developed an interesting forecast model for the very-low-frequency waves that occasionally are experienced along the Dutch coast. The model is based on an autoregressive moving average model that uses observations on the platforms and buoys in the North Sea to provide the predictions along the coast. It apparently has been very successful and is more accurate for these waves than is the KNMI operational wave model. The KNMI model can easily miss the long waves that are generated primarily outside the model domain. It also is used by HMR for their forecasts.

Ir. Leo de Vrees' group is mostly involved in extending the circulation models to finer resolutions and to 3-D. The developments are driven by the needs of finer forecasting information in the complex topography near harbors and by the needs of modern society for water quality forecasts. A version of the WAQUA model is run at 8-km resolution, half the spacing of the operational model. A 3-D sigma transformed model, TRIWAQ (3-D WAQUA), has been developed in cooperation with Delft Hydraulics for salt intrusion studies. Also, a coastal strip 3-D model, KUSTSTROOK, has been developed to study coastal erosion, sedimentation, spoil dispersion, and water quality (salt intrusion and dissolved and particulate contaminant transport). This group also advises other authorities (Water Boards) on dike maintenance and standards of construction, taking into account previous work they have performed on combined analyses of failure mechanisms. This has obtained especially

high visibility in the last few years due to recognition that the Dutch sea level is rising.

Discussion and Conclusions

Operation of the various models at RWS is interesting because their accuracy or otherwise has an immediate impact on the public at large. The advisory service that is provided to warn of low water in the Rhine entrance channel to Rotterdam is a particular example that has huge economical consequences for the harbor of Rotterdam and the surrounding population. The principles in the model are well worked out, the data required to operate the model are obtained, and the model is run to provide the grist for the forecasts. The only manual procedure is to check the output of the forecasting models and the actual final drafting of messages to their long list of customers.

The scientists and engineers at RWS have many associations with their colleagues in nearby countries. However, not many contacts are apparent with U.S. scientists and engineers, who clearly are interested in similar goals and problems.

Finally, RWS potentially has a problem with the current plans for the commercialization of KNMI.

DELFT HYDRAULICS

Delft Hydraulics, located in Delft and in Emmeloord, is one of the many large hydraulics research and engineering laboratories in Europe. (Others include Danish Hydraulics near Copenhagen [see accompanying article on Denmark]; DHL in Trondheim [see accompanying article on Norway]; Laboratoire Nationale Hydraulique, Chatou, France; Technical University of Braunschweig, Germany; and Hydraulics Research in Wallingford, U.K.). Primary interests at Delft are coastal and offshore structures and sediment problems that are associated with these structures, coastal morphodynamics, and associated disciplines. Reference 1 provides a recent review of research at Delft Hydraulics; ref. 8 provides information on the EC MAST program on coastal morphodynamics, which is led by Dr. Huib J. de Vriend of the Emmeloord facility of Delft Hydraulics.

NETHERLANDS INSTITUTE OF SEA RESEARCH (NIOZ)

NIOZ is a teaching institute of the Netherlands Organization for the Advancement of Scientific Research (NWO). It has about 50 staff members and roughly an equal number of students, with 8 successful Ph.D.s having graduated in 1992. NIOZ is located on the island of Texel, which separates the very shallow Wadden Sea from the North Sea. The research at NIOZ is divided into a number of programs: multidisciplinary, chemical oceanography and pollution, physical oceanography, marine geology and geophysics, benthic systems, pelagic systems, and coastal systems.

Three interdisciplinary programs of general oceanographic interest are the Netherlands Indian Ocean Programme (NIOP); the Joint Global Ocean Flux Study (JGOFS) with close coordination with German, British, and French participants in the Southern Ocean; and a Benthic Links and Sinks in North Sea Nutrient Cycling (BELS) program. They have international connections with the World Ocean Circulation Experiment (WOCE), with repeat sections in the North Atlantic, analyses of mixing in the Iceland Basin in the DUTCH-WARP project, and cooperative work in the Greenland Sea Project.

Of interest in the area of coastal oceanography are several programs of physical and optical studies. Theoretical research has been carried out on nonlinear tidal dynamics, with both deterministic and chaotic flows by Dr. J. Zimmerman. A joint observational and modeling program, the Integrated North Sea Project (INP), is studying diapycnal mixing events in physical-biological processes in the lower trophic levels in seasonally stratified water in the North Sea. This was co-organized by Dr. H. Lindeboom. There is ongoing joint research with the U.K. Coastal Optical Remote Sensing Airborne Radiometer (CORSAIR) deployed by the U.K. Natural Environment Research Council, and initial work with a new 22-channel underwater transmissometer constructed in-house (pursued by Dr. M. Wernand). Its purpose is to determine algorithms for the inversion of remote sensing color data for biological and sediment transport in the Dutch coastal zone. Drs. H. van Aken and

J. Zimmerman have joint work with Dr. Chris Garrett of Canada on shelf edge processes observed in an experiment in the Bay of Biscay.

In research on coastal modeling, development of a benthic nutrient model is continuing in the MAST project European Regional Seas Ecosystem Model (ERSEM). Initial results have been carried over from MAST I to the second phase of MAST support, MAST II. In addition, the ECOWASP model (Wadden Sea Ecosystem Model, where WASP also stands for the MAST Wadden Sea Project) is a combined physical, geomorphological, and ecosystem model that is being extended in coordination with Dutch, German, and Danish institutes.

DISCUSSION ON THE NETHERLANDS

Several points require further discussion here. First, this is the first country I visited that expressed serious concern about validating models that are being developed for future operational use. This point was made by scientists at both RWS and KNMI. They are reasonably content with the quality of predictions of the present models, for the specific things they were designed for, because they have been able to properly validate the accuracy of the results. However, they worry about how to validate the predictions of 3-D models, sediment transport models, or in their view even more difficult, ecological models, when they actually have little data on the present state of the ocean and little confidence that data will be available as necessary for more complex models being developed for the future. This is an extremely important point. The conclusion has to be that the development of new models has little in the way of coordinated developments on how to provide these models with the data that will be required to maintain them, or even to validate their accuracy for that matter.

A second point is that various models are being developed in a large number of institutes in The Netherlands, both in government laboratories and in universities, and the work reported in this report is only a fraction of the total.

REFERENCES

1. T. H. Kinder, "Delft Hydraulics," *ESNIB* **91-07**, 18-20 (1991).
2. G. Burgers, "A Guide to the NEDWAM Wave Model," KNMI Report WR-90-04, 1990, 81 pp.
3. G. Burgers, V. Makin, G. Quanduo, and M. de las Heras, "Wave Data Assimilation for Operational Wave Forecasting at the North Sea," 3rd International Workshop on Wave Hindcasting and Forecasting, Montreal, May, 1992, 202-209.
4. G. K. Verboom, J.G. de Ronde, and R.P. van Dijk, "A Fine Grid Tidal Flow and Storm Surge Model of the North Sea," *Continental Shelf Research* **12**(2/3), 213-233 (1992).
5. C. Mastenbroek, G.Burgers, and P.A.E.M. Janssen, "The Dynamical Coupling of a Wave Model and a Storm Surge Model Through the Atmospheric Boundary Layer," *J. Physical Oceanography* (in press).
6. G. Burgers and V.K. Makin, "Boundary-layer Model Results for Wind-Sea Growth," *J. Physical Oceanography* (in press).
7. N. Maat, C. Kraan, and W.A. Oost, "The Roughness of Wind Waves," *Boundary-Layer Meteorology* **54**, 89-103 (1991).
8. T. H. Kinder, "Coastal Morphodynamics: A European Community Marine Secience and Technology Research Program," *ESNIB* **91-07**, 25-27 (1991).

Contacts

Koninklijk Netherlands Meteorological Institute
Dr. Gerbrand Komen
Head, Physical Oceanography Department
Postbus 201
AE de Bilt, NL-3730 The Netherlands
Phone: +31 30 20 6911
Fax: +31 30 21 0407
Omnet:KNMI

Rijkswaterstaat Noordzee Directorate
Ir. Derrik Bakker
P.O. Box 5807
Rijswijk 2280 HV, The Netherlands

Phone: +31 70 336 6668
Fax: +31 70 390 0691

Rijkswaterstaat Tidal Waters Directorate
Ir. Henk Keyser or Ir Leo de Vries
Koningskade 4
Den Haag, The Netherlands
Phone: +31 37 44 549
Fax: +31 37 45 169
E-mail: keyser@dgw.rws.nl

Delft Hydraulics
Dr. J.K. Kostense
Head, Hydrodynamics Section
P.O. Box 152
8300 ad Emmelrood, The Netherlands
Phone: +31 52 74 2922
Fax: +31 52 74 3573

Netherlands Institute for Sea Research
Dr. W.G. Mook, Director
P.O. Box 59
1790 AB Den Burg
Texel, The Netherlands
Phone: +31 2 22 06 93 00
Fax: +31 2 22 01 96 74
Omnet: NIOZ.TEXEL

NORWAY

INTRODUCTION

Coastal prediction systems are operated in Norway by a unit of the Norwegian Meteorological Institute and by Oceanor, a private company that services fish farming and offshore operators. Research in related areas is also undertaken by these activities as well as by SINTEF (Foundation for Scientific and Industrial Research of the Norwegian Institute of Technology), the Nansen Environmental and Remote Sensing Centre, the Geophysics Institute of the University of Bergen, the IBM Bergen Environmental Sciences and Solutions Centre, and the Norwegian Polar Research Institute. The last intensive review of oceanographic research in Norway was completed in 1987.[1]

NORWEGIAN METEOROLOGICAL INSTITUTE (DNMI)

The main location for national forecasting services in Norway is the Meteorological Institute (DNMI, Den Norske Meteorologiske Institutt). Its headquarters are in Oslo, and regional offices are in Oslo, Bergen, and Tromso. Marine services are the responsibility of headquarters in Oslo, but their primary strength in the marine area historically has been at the Western Regional Office in Bergen. New developments primarily are the responsibility of the Program for Ocean Surveillance and Forecasting (HOV). HOV is the national agency for coordinating ocean environmental monitoring. It is the core of the Norwegian contribution to international environmental monitoring as well as improving services to safeguard life, property, and the environment in the coastal zone. The services include forecasts and status reports of marine meteorology, waves, tides and surges, currents, ice, temperature, and salinity; the chemical and biological state; transport predictions of these substances; environment management of spills; and analysis of climatic trends. Users of the information are fishing, pollution control, and coastal authorities; the Navy; shipping; and marine research institutes. These are lofty goals and tasks, and the funding level is much too small to realistically do more than a few of these tasks well.

Both HOV and the Western Regional Office are located in offices on the campus of the University of Bergen. HOV is headed by Dr. Johannes Guddal, who was an active participant in the WAM Group for wave forecasting. Expertise in physical oceanography and circulation modeling is provided by Dr. Henrik Soiland. HOV is a 3-year project (initially funded in 1990 and begun in 1991) with the goal of updating the marine services of DNMI. It was funded primarily because of an erroneous storm surge forecast in Oslo Fjord and increasing problems that fish farmers have with algal blooms. Interestingly, Dr. Ola Johannessen of the Nansen Centre (discussed in a later section) was primarily responsible for this program as the result of his organization of a large, interdisciplinary meeting in response to these problems.

The primary input to the ocean models is provided by the meteorological forecast. This is run in Oslo with a limited area atmospheric model having 50-km resolution (called LAM50S) that uses the ECMWF forecast for initialization and maintenance of boundary conditions. The model run is actually made on the Cray at SINTEF in Trondheim (see later section for additional information on SINTEF). Cloud images from both geostationary and polar-orbiting satellites are used in Oslo to identify fast developing systems (polar lows) to improve short-range forecasts.[2]

The storm surge model uses the wind stress (using Large and Pond formulation) and air pressure of the meteorological model to make forecasts twice per day out to 48 hours. The numerical simulation uses a Blumberg-Mellor model (ECOM-3D, 3-D Estuarine Coastal Ocean Model) that is run in the barotropic mode with 20-km resolution and a 12-h hindcast to get it started. The run is made without tides, and these are linearly added after the calculation. The results of the storm surge analysis are checked with time series of 22 tide stations that are in various harbors and coastal locations. The data are monitored by the duty forecasting watch at the Bergen office of the Meteorological Institute, and they notify the appropriate authorities in case of extraordinarily high water. Quoted errors typically are 15-cm rms with worst case 25-cm rms, but Dr. Soiland is concerned about the value of rms values. He believes the statistics of extremes are more interesting and important, and he presently is researching this issue by calculating their statistics and studying the implications.

The operational wave model (NOWAMO, Norwegian Wave Model) is a hybrid model (second generation). It combines a parametric formulation for the development of the windsea with a system of freely propagating swell components. The windsea spectrum is specified (originally as a Neumann-Pierson model), with squared cosine directional components centered on the local wind direction. Source and sink terms are specified as per Odd Haug (unpublished) in a numerical integration of the energy balance equation of the energy level and cutoff frequency in the wind sea. The swell component is calculated only for selected locations. The windsea within the preceding 48 hours (actually calculated only every 6 hours, and split into intervals of 2-second period) is regarded as swell potential. The calculation is a sum of those components that travel to the specific location (hindcast calculation) with their group speed of the dominant peak. Finally, the sea and swell are combined at the specified location. The grid spacing has been quoted variously as 150 km and 50 km. Dr. Guddal has been involved with the WAM program, so he is familiar with recent upgrades and with the present ECMWF wave product. There is no Norwegian model for propagating the waves into the complicated geometry of the inner coastal zone.

In addition to the storm tide and waves forecasts, DNMI provides an ice forecast twice weekly. The analysis uses satellite and occasional ship observations of the ice edge along with an ice edge model that uses the wind forecast and climatic currents. It was developed by Dr. Eivind Martinson in the Oslo office.

HOV also provides an algae weekly report that is based on the analysis of two biologists in the Bergen office. They use information on algae species from water samples provided by observers along the coast. A qualitative forecast is made on the basis of the meteorological forecast. Two marine biologists located at HOV perform the species identifications and make the assessments in the weekly report.

Finally, there has been some research on 3-D circulation models. The ECOM-3D model (same as above) has been run in the baroclinic mode for the Norwegian and North Seas using climatic data (a combination of Levitus and Damm data sets for density field, various sources for freshwater input of rivers in the North Sea and the Baltic outflow, and monthly mean DNMI winds). There is no present effort at HOV to implement an operational 3-D circulation model.

OCEANOR

The Oceanographic Company of Norway (Oceanor) is located at the harbor in Trondheim; because of its commercial interests, it spun off from SINTEF in 1984. Oceanor provides a range of oceanographic and meteorological services including field operations, surveys, and instrumentation deployment and maintenance. One instrumentation package that is widely used in the

Norwegian offshore industry is their integrated data collection, processing, and presentation system called MARCO. This system combines data from sensors on many elements of marine structures.

They also are heavily involved in offshore buoys, although the actual buoy construction is done by Seatex. Seatex is an offshore design and manufacturing company that shares space in the same building. More on the buoys later.

Oceanor has an interesting operational forecasting system (Seawatch) that directly supports offshore oil and fish farming activities. Seawatch is a combination of an operational buoy network and a forecasting system; it provides real-time data on many meteorological and oceanographic parameters. The Seawatch Europe Project is run by Dr. Svein Erling Hansen, and the network includes 10 buoys around Norway including ones in the North Sea, Baltic Sea, and Barents Sea. There also is a Seawatch project in the Gulf of Thailand with a network of seven buoys. These systems have an Argos link to a central computer that collects the data, performs quality checks and calibrations, and processes the data. In addition, many more observers, mostly fish farmers, along the Norwegian coast provide temperature, salinity, water clarity (Secchi disk depths), and in special cases, water samples for bioassays.

The data are used to provide forecasts that are prepared every morning and distributed by phoneline to multiple users. The unit has a staff of 10; two are on watch in their operations center every morning to prepare the daily forecasts. For example, for waves, the results of the numerical forecasts made by the Norwegian Meteorological Institute are evaluated and compared with the buoy data before an actual forecast is made. Output includes data fields and a written text of the assessments and forecasts.

The buoy in the southern Baltic Sea recently detected the first bottom-water renewal in many years; another in the central Barents Sea has a radionuclide detector that is of particular interest. This instrument, called RADAM, has a 3-in. NaI crystal with a 1024-line gamma ray spectrometer, providing perhaps 20 Bq threshold for the Cs-137 line. Along with the other buoy data, these data are transmitted to Oceanor via the Argos system. Sivert Moen is the local nuclear expert, and he has more information on this sensor package. It is a unique capability for monitoring the water on the northern shelf that perhaps has been contaminated by the Russians by their well-known dumping of nuclear waste and reactors. Oceanor is interested in putting in more of these buoys for long-term monitoring on the northern shelves and seeks any U.S. interest.

Dr. Karl Tangen is a member of this group; he previously was at the University of Oslo. He works on identifying toxic algae for the Seawatch Europe Project. He has developed an interesting guide to more than 400 dinoflagellates. It has both textual and graphical aids for identifying unknown algae in water samples that have been sent to the laboratory. This aid and an accompanying database are available on the Linnaeus database on CD-ROM. He has a very useful capability to display microscope samples on a large screen alongside a choice of examples from the disk archive. This is a powerful aid that several observers can use to discuss the relative merits of potential matches between the samples and the known species in the archive. This is especially useful so that he does not have to be present every morning to personally make all identifications of offending dinoflagellates.

After identifying an offending species, the forecast data on weather and currents are used to make a prediction of the progress of potential blooms along the coast and estuaries where fish farms are located. A textual assessment, including a warning if warranted, is provided along with useful graphical material to all subscribers of the service.

Another component of the forecasting service is a prediction for the offshore industry of the magnitude of currents along and offshore the southwest coast. The need is to provide warning of high currents since offshore platforms and operations are especially sensitive to them. The procedure for this forecast is an empirical combination of wind data and an "upstream" buoy over several previous days. It relates large currents with an alongshore Kelvin wave that travels up the coast at known speed after a large volume of light, freshwater is released from the Kattegat where it may have been retained for many days by an adverse wind. This methodology was originally developed by Dr. McClimans, whom we will discuss later in the section on SINTEF.

They have a 3-D numerical model called HYBOS that is said to provide water level, currents, and density (temperature and salinity), although not much was diclosed to me about it, and I gather it is not very useful to them. I would be surprised if it were accurate. The coastline of Norway is very rough, and there simply is not enough real-time data from the limited number of buoys and coastal stations to provide a reasonable numerical analysis and forecast of water currents and density structure. They also obtain a copy of the results of the HOV circulation model, and use these as necessary to estimate currents near the coast.

Oceanor also provides forecasts for the drift, evaporation, and entrainment of oil spills from offshore platforms or ships. These are based on actual wind forecasts (although constant in value over the period of the calculation), but the water current input comes only from an archived database.

In addition to the forecasting service, they have ongoing research activities in areas of interest to their customers. Dr. Stephen Barstow is involved in some interesting work with surface wave data. He was involved in WAVIC, the comprehensive wave buoy intercomparison that was undertaken by the European offshore research and offshore industry a few years ago. He now is analyzing archived GEOSAT altimeter data to calculate a wave climate for the Norwegian Sea. Accurate estimates of the wave climate are very important for the offshore industry because they are used to specify many characteristics of the design of all new structures. Any increase in height of structures off the water, for instance, comes at a very high price. The importance of this new work is that the GEOSAT data provides much more complete geographical data than heretofore available.

He has the surprising result that the wave climate has been much more severe in the winters since 1989 than in the available records before that time. The increase in significant wave height is about 50%, an enormous figure by anybody's measure. The previously estimated 100-year conditions have now been exceeded many times in the last three years. Although of major importance to the offshore industry, the interesting research issue is what to make of this. It may be a statistical anomaly and, if so, it is way off the distribution curve. But what of the anomaly? Perhaps there is a "groupiness" of stormy years that actually could be a normal occurrence if statistics were available over many years. Or, perhaps the "climate" has really changed markedly for the worse (in the sense of roughness of the Norwegian Sea). In either case, what is the meaning of stationarity in this context?

Finally, it is worthwhile returning to the subject of the Oceanor buoys, which are called TOBIS buoys. These buoys are unique in their construction, and they comprise a vital monitoring component of the forecasting system. Buoyancy is provided by a 1-m sphere that rides at the surface. Three 6-m-long rods are attached to and located around the sphere. The upper half of these rods elevates the sensors above the surface; the lower half provides depth for the underwater sensors and distributes the weight for stability. They are tethered off a subsurface mooring buoy and are reasonably lightweight (450 kg). This allows for easy handling during deployment and retrieval. Typical sensors are mounted for waves, wind, air temperature and pressure, water currents, multifrequency transmittance for algae, nutrients, oxygen, radioactivity, and temperature-salinity profiles.

These buoys are critical elements of the Seawatch Europe System, and they logically are deployed at locations considered critical to the forecasts. Their data are considered additional to those obtained from the coastal stations and the Norwegian Meteorological Institute forecasts, but they are heavily relied upon for users of the forecasts in their immediate locations.

This brings up a subject of primary importance. There is a serious problem with forecasts of oceanographic parameters other than water level, waves, or barotropic currents. This problem is that there is never enough real-time data for the 3-D density and velocity structure in the ocean. Thus, the models badly under-resolve the spatial scales of the major features that determine the fluctuations in the density and velocity of the water. This problem is fundamental to all near-term advances in ocean forecasting capabilities, and it is not unique to Norway or even to other countries in western Europe.

NANSEN ENVIRONMENTAL AND REMOTE SENSING CENTRE (NERSC)

The Nansen Environmental and Remote Sensing Centre (NERSC) is located in Bergen, not far from the University. They have several programs of interest in this area, although they are most widely known for their work in the Arctic through the efforts of their director, Dr. Ola Johannessen. One example of this work was the involvement of Dr. Johannessen during the ONR MIZEX (Marginal Ice Zone Experiment) programs of some years ago. In the area of shallow-water work, they recently were part of the SIZEX 92 experiment. This experiment involved both physical oceanography and underwater acoustics propagation across the marginal ice zone in the Barents Sea.

They are experts in interpreting synthetic aperture radar (SAR) images of sea ice. Drs. Johnny Johannessen and Stein Sandven are continuing this work; they have extensive experience in real-time operations. They used ERS-1 SAR images to help route the French ship *L'Astrolabe* across the Northern Sea Route during the summer of 1991, providing the ship with interpretations of images as to best navigation route. This work has been published in the past year, with a number of interpretive analyses of the ice on the shelves of northern Russia. The most interesting result is the difficulty of using the SAR data to discriminate ice type or even ice from open water in the melting season.

NERSC plans more operations of this type with the Russians in the near future. They also imaged the Norwegian Coastal Current many times over 6 weeks in NORCSEX 91, a multi-institution remote sensing experiment (in cooperation with the Naval Postgraduate School and the Environmental Research Institute of Michigan). They obtained strong correlations of SAR features with ocean fronts as seen by a research vessel and observed in multiple AVHRR (very-high-resolution radiometer) images. More on this later. It is an important point and is the real reason that work at NERSC is directly applicable and of primary importance to the coastal work that is our focus. For the near future, they expect to provide their quick-look SAR interpretations of images to research vessels in the Rocky Road experiment. They also have a developmental contract with the (U.S.) Naval Research Laboratory-Stennis. This is a follow-on of the NORCSEX 91 analysis in the area of automatic classification of features that are exhibited in the ERS-1 SAR data.

Dr. Johannessen also is planning joint work with Russians on water quality in the Kara Sea, where nuclear dumping has occurred. He has been instrumental in the planned Nansen Centennial Drift Project. This is a two-year drift of an ice-hardened ship across the European Basin of the Arctic, as a centennial repeat of the Nansen drift. Again, more on this later. This is more interesting for polar oceanography than for coastal oceanography, but well worth investigating the opportunity for mutual benefits. NERSC has formed a joint research institute with scientists from the Arctic and Antarctic Research Institute in St. Petersburg. It is located in St. Petersburg and is called the Nansen International Environmental and Remote Sensing Center (NIERSC).

Finally, detailed planning has begun for a 5-year pilot study to develop an operational marine monitoring and modeling system for fjords and coastal waters, a project called MOMS. So that it does not directly conflict with the work of HOV, the planning for this program emphasizes water quality. It necessarily includes some new physics, but the emphasis is on chemistry and biology. In the plan, NERSC would be the lead institute in a large coordinated program involving many Norwegian institutes and agencies.

The plans are worth tracking for two reasons. First, Dr. Johannessen has been very successful in developing such programs in the past, so there is high probability that the plan will be implemented. Second, and this returns to a point made earlier, remote sensing must play a necessary part in providing high-resolution spatial information for analysis and forecasts of future coastal models. This is the Achilles heel of all high-resolution baroclinic models that I have seen in Europe (as well as in the U.S., actually). There just is not enough detail in the observations to properly initiate or maintain realistic models of the circulation in the coastal zone. And, simple extensions of altimeter or AVHRR data to the coastal zone will not be adequate to solve this problem.

This institute has an excellent history of interpretation and use of remote sensing data; it has specific experience in interpretation of SAR data that is available in cloud-covered regions; and it

has a step up on others rest in attempting to provide the necessary observations for the model. NERSC personnel have experimented with assimilation of SAR and AVHRR data into numerical models of the coastal zone circulation, but results to date are inconclusive.

SINTEF

The SINTEF Group, or SINTEF for short, is an association of five large R&D organizations, including the original institute called SINTEF (Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology). It is a nonprofit organization of 2300 employees and is itself made up of a number of semi-independent institutes who are loosely related through their association with the university. An example of direct interest here is the Norwegian Hydrotechnical Laboratory (SINTEF NHL, with 140 technical personnel) that pursues R&D in the field of hydroscience, mostly in marine environment. The private company, Oceanor, was part of SINTEF NHL, but it spun off when its specific client needs and interests exceeded its R&D interests.

NHL has a polar technology and ice engineering group where Dr. Tom McClimans runs a particularly interesting facility. It is a 5-m diameter rotating tank model for studying the circulation of selected ocean regions. He is well known for his discovery of a remote technique for estimating tidal excursions in remote polar regions. He noted that images of icebergs that are grounded in shallow water exhibit wake trajectories in the thinner ice, and these can be used to estimate the tidal excursions. Returning to his rotating table, it is exceeded in size only by the very large table at Grenoble, France. (The use of such tables seems to be more prevalent in Europe than in the U.S. Rotating tables are operated by Davies at the University of Dundee, d'Hieres at Grenoble, van Heist at Eindhoven, Linden at the University of Cambridge, and Bubnov in Moscow.)

These tables are especially useful for studies of buoyancy-driven flows such as river plumes in coastal regions and dense water outflows from shelf regions. Dr. McClimans' table uses salinity stratification that is stable for many hours for each run. This enables a range of diffusive to basin scales—much larger than equivalent numerical models, although the specific range depends on the definition of the "effective diffusivity." His is really a good model for buoyancy-driven flows, such as the production of heavy water that occurs on relatively shallow polar shelves. He has a model of the Vestfjord on the west coast of Norway, and he now is running a model of the Barents Sea (for several sponsors, including Thomas Curtin of ONR). Both models provide interesting results; many recognizable ocean features plus several additional ones are now being studied in more detail.

Also, in keeping with the other hydraulics laboratories in Europe, NHL has a full range of wave-prediction models for use in designing harbors and coastal structures. These include a model for propagation of waves into a complicated coastal region, including current and bathymetric refraction but no nonlinear effects, and a model to calculate harbor resonances and diffraction-refraction in the vicinity of breakwaters and other structures.

Dr. Harald Krogstad of the SINTEF Industrial Mathematics Institute works in several areas of direct interest to improving ocean models. He has derived an inversion algorithm that estimates surface wave spectra from observed spectra of SAR images, and claims it is simpler than the well-known Hasselmann inversion technique. They appear to interact quite often. He also has results of an interesting wave climate analysis (with Dr. Barlow at Oceanor) that is based on the GEOSAT altimetry data set. Finally, he has implemented the hydrodynamic equations on a 56-processor Intel parallel computer that they have, and works with a small group developing a "parallel computer language" for general-purpose scientific computing. His group has a versatile graphics package written in C with GLview graphics calls. This package provides interesting high-speed plots for 3-D data sets that result from complicated hydrodynamical and structural problems. The Industrial Mathematics Institute is part of ERCIM, the European Research Centers on Informatics and Mathematics, and will host this year's ERCIM Workshop. This workshop has a strong session on interactive modeling, simulation, and visualization in large-scale scientific computing. Dr. Krogstad's group also runs the Norwegian Cray supercomputer that is used by multiple agencies in Norway.

Dr. Krogstad's interests in surface waves extend beyond the interpretation of altimeter and SAR data from satellites. He has developed algorithms for optimal analysis (as in maximum likelihood method) of data from pitch, roll, heave buoys, and has written a number of papers on the applications of these to data from wave buoys in the last few years. In conjunction with Lee Gordon of R&D Instruments (RDI) in San Diego, CA, and Martin Miller of Exxon Production Research in Houston, TX, he has developed a methodology for using data from horizontally mounted acoustic doppler current profilers (as mounted on the leg of an offshore platform) to estimate directional spectra. This methodology has been successfully applied to observations in the Odin field in the Norwegian Sea. Spectral resolution appears to be better than that obtained with single directional wave buoys. He also has an interesting algorithm that uses observed very-low-frequency swell data to hindcast the location and strength of storms in the North Atlantic.

The SINTEF Automatic Control Institute is best known for control technology for autopilot systems for ships and subsea vehicles, dynamic positioning of ships and platforms, and control systems for subsea inspection vehicles and robotic maintenance of subsea installations. However, Dr. Dag Slagstad of SINTEF Automatic Control has had a long commitment to developing models for the Norwegian fishing industry. He has developed two baroclinic hydrodynamical models that are used for research purposes, one for the long Norwegian coastal region and the other for the Barents Sea. His group has emphasized phytoplankton and zooplankton models that are run in parallel with the physics models. He works closely with fisheries biologists. They use in situ point measurements obtained from ships along with previously archived color images from the U.S. Coastal Zone Color Scanner for verifying specific features in the simulations. They have many publications on this work, but someone more familiar with biogeochemical modeling would have to assess the uniqueness and value of this modeling work.

NORWEGIAN POLAR RESEARCH INSTITUTE (NPRI)

NPRI is locted in near the airport in Oslo. They have a lead in the Nansen Centennial Arctic Programme (mentioned previously), which is intended to be a modern repeat of Nansen's two-year drift across the Arctic by a ship that is frozen into the ice. It is aimed toward issues associated with Arctic sciences, particularly global warming, but it includes components of more general ONR interest.

One such component, aimed toward air-ice-ocean exchange and circulation processes, is very interesting, as is a mapping and monitoring component. It is expected to have about two-years duration, 1994-95, with several additional years for data analysis. It presently is a funded Norwegian program, and it merits attention. This component will provide a convenient station for add-on experiments that cannot be accomplished with drifting buoys or with short-duration manned ice camps. Because this is a Norwegian project, it has been planned only among Norwegian organizations in Oslo, Tromso, Trondheim, and Bergen. They plan for 10 man-years' non-Norwegian participation during the expedition in addition to 50 man-years' Norwegian effort. The cost is high (approximately 160 M NOK, or $25 M). The project requires a specially outfitted new ship in addition to the manpower level, but it typifies the seriousness of the northern countries in their Arctic research. A preliminary science plan is available, although the final decision of full funding from the Norwegian government is not yet decided. This project is important in the context of coastal modeling only because of our general ignorance of the importance of the vast northern shelves and their production of intermediate water on the interior circulation of the Arctic.

Dr. Bjorn Erlingsson (formerly associated with this laboratory but now in Iceland) was the first western scientist to have spent considerable time on one of the Russian North Pole camps. This was organized as part of the Soviet Norwegian

Oceanographic Programme (SNOP), and he accompanied the NP-31 ice camp (for only a short period of time compared with its 2.5-year lifetime).

In addition to this joint research effort, NPRI has worked with the Russians on several other occasions more associated with shallow water. They are involved in other joint observations in SNOP (moorings and CTD lines in the Barents Sea); they are part of the Ice Data Acquisition Programme with oil company support for tracking icebergs by using Argos drifters (often in the Russian Economic Zone); and they are part of the Northern Sea Route Project. This latter project is in the planning stages, with only preliminary studies to date. The only reports I have seen are a preliminary environmental assessment written by a Norwegian scientist and a summary of a multinational meeting that discusses the results from Phase I (largely planning) of the Project.

UNIVERSITY OF OSLO

Professor Bjorn Gjevik has an ongoing research program that is studying circulation processes on the western shelf of Norway. He uses numerical models to study the primary processes that generate extreme currents on the shelf. These studies provide information for the optimal engineering design of offshore platforms. The work explores the effects of high wind stress during storms and the effects of topographical variations on the currents on the mid-Norwegian shelf, including the region of the Haltenbanken. He uses a Mellor model of the local region (12-km resolution), with hindcast wind stress. He also has recently completed work on an atlas of tides in the Arctic. This atlas was assembled from the output of a tide model that includes the Arctic Ocean and surrounding regional seas, including the Barents Sea and the entire Norwegian Sea down to the latitude of the U.K. The predicted tidal currents have been compared with available current meter data in the Barents Sea with good results, and they are in press.

Finally, Professor Gjevik is analyzing data from the Ocean Data Acquisition Project (ODAP). This includes using the results in developing shelf models in the Meteorological and Oceanographic MOdeling Program (MOMOP) program. (Contact for ODAP/MOMOP is Lars Eide at Norsk Hydro A.S.) He also has been analyzing hindcast model data and observations in the Haltenbanken area with a developmental Mellor model that is expected to be operational in the future.

GEOPHYSICS INSTITUTE OF THE UNIVERSITY OF BERGEN

Professor Arne Foldvik and Dr. Tor Gammelsrod at the Geophysics Institute of the University of Bergen are involved in research on the production of heavy water on the continental shelves in polar regions. This work continues with observations of circulation on the northern shelves (in SNOP, mentioned above) and in the Waddell Sea.

IBM BERGEN ENVIRONMENTAL SCIENCE AND SOLUTIONS CENTRE

This research center is located in the same building as the Program for Ocean Surveillance and Forecasting (HOV, previously described) on the campus of the University of Bergen. It was originally set up by IBM with corporate funding to provide a link between the parent organization and environmental interests. But it has been relegated to paying its own way, now that the IBM coffers are dry. They have several developments of some interest in our context. An oil spill management system (NRDAM, Natural Resource Damage Assessment Model) has been developed in coordination with Applied Science Associates (ASA) in Narragansett, Rhode Island. It provides a useful tool to aid the management of an oil or chemical spill in the marine environment. However, the numerical model has little real-time environmental input such as a varying wind speed or the real structure of tidal currents. The original model was developed by ASA for use in pollution asessment (as defined by the U.S. Superfund Law) on the basis of determining the cost of various environmental hazards. Its emphasis on this aspect of the problem while simultaneously using very unrealistic and unreliable environmental models (such as they are today) is of very limited utility, in my opinion.

They also have developed ADVIZE, an Advanced Data Visualization Environment, that uses modern computer graphics to visualize scientific data. It provides color graphics for scalar and

vector field mapping and several types of volume rendering on an IBM RISC System/6000 platform. This has been developed for a perceived market in several fields, including ocean modeling and simulation. In addition, they have developed software for managing multiple simulations and the extensive database that serious use of these systems requires. It presumably was developed for the offshore industry to assist in management of volumetric databases for sub-bottom structure, but it has been extended for wider use in the modeling community. They are interested in talking with potential users of these types of display and management systems.

Finally, Dr. Alastair Jenkins has developed a new methodology for using a wave prediction model for driving a near-surface current model. It actually is a unique attempt to combine a wave prediction model and a hydrodynamic model to more accurately predict near-surface currents. If the results turn out to agree with observations as well as they initially appear, this could be an important development for predicting surface drift. Certainly, a breakthrough is needed to advance beyond the usual assumption in most oil and chemical spill models that the slick or other contaminant moves downwind at some fixed fraction of the wind speed. It also could be useful for calculating the drift and dispersion of plankton, fish eggs, and larvae of marine organisms. In this work, the source terms in the tail of the energy spectrum of the surface waves are used to balance the wave energy, momentum, and action. To achieve the balance, a fine-resolution 1-D numerical model is solved in Lagrangian coordinates of the significant waves for the second-order perturbations near the surface, along with an assumed model for the eddy viscosity profile.

REFERENCES

1. J. Williams, "Oceanographic Research in Norway," *European Science Notes* **41**(8), 439-442 (1987).

2. J. Dugan and P. Twitchell, "Polar Lows Research," *ESNIB* **92-02**, 38-40 (1992).

Points of Contact

Norwegian Polar Research Institute
(new name: Norsk Polarinstutt)
Dr. N.A. Oritsland, Director
University of Oslo
P.O. Box 158
N-1330 Oslo Lufthavn, Norway
Phone: +47 2 123 650
Fax: +47 2 123 854

Norsk Hydro A.S.
Lars Ingolf Eide
P.O. Box 200
N-1321 Stabekk
Phone: +47 22 73 83 80
Fax: +47 22 73 78 70

SINTEF
Dr. Thomas McClimans
Norwegian Hydrotechnical Laboratory (NHL)
N-7034 Trondheim, Norway
Phone: +47 7 592 300
Fax: +47 7 592 376
Omnet: J.SAETNAN (pass to McClimans) or H.KROGSTAD

Oceanor
Svein Tryggestad, Director
Pirsenteret
N-7002 Trondheim, Norway
Phone: +47 7 52 50 50
Fax: +47 7 52 50 33
Omnet: OCEANOR

Norwegian Meteorological Institute (DNMI)
Dr. Johannes Guddal
Allegt. 70
N-5008 Bergen, Norway
Phone: +47 5 23 66 00
Fax: +47 5 23 66 01
E-mail: henrik@hurricane.bergen.dnmi.no

Nansen Environmental and Remote Sensing Centre
Dr. Ola Johannessen, Director
Edvard Griegsvei 3A
N-5037 Solheimsviken/Bergen, Norway
Phone: +47 5 297 288
Fax: +47 5 200 050
Omnet: O.JOHANNESSEN

Geophysics Institute
Professor Arne Foldvik
University of Bergen
Ruskenshaugen 35
N-5060 Bergen, Norway
Phone: +47 5 212 653
Fax: +47 5 212 070
E-mail: ngfaf@uib.no

IBM Bergen Environmental Sciences and Solutions Centre
Dr. Pat Gaffney, Director
Thormohlensgate 55
N-5008 Bergen, Norway
Phone: +47 5 54 46 20
Fax: +47 5 96 01 15
E-mail: chrisgie@bsc.no

University of Oslo
Professor Bjorn Gjevik
Department of Mechanics
P.O. Box 1035
Blindern, Oslo 3
Phone: +47 22 855 856
E-mail: bjorn@math.uni.no

DENMARK

INTRODUCTION

The institutes in Denmark that have operational systems or have research and development programs to improve them are the Danish Meteorological Institute (DMI) and the Danish Hydraulics Institute (DHI). In addition, there is a smaller amount of relevant work at the Danish Maritime Institute and the Geophysics Institute at the University of Copenhagen.

DANISH METEOROLOGICAL INSTITUTE (DMI)

The Danish Meteorological Institute (Danmark Meteorologisk Institut, or DMI) is among those in European countries that have operational tide-surge models for forecasting water levels to provide warning of coastal flooding conditions. A disastrous flood caused by a storm in 1872 was instrumental in the founding of the Institute. More recent floods created enough interest from the Danish government to develop an operational surge model in the 1960s. That model has been superceded by the present one, which has been in operation for about three years. The model uses meteorological data for the wind forcing from the U.K. Meteorological Office. It includes periodic tide forcing at the northern and southern boundaries of the North Sea. The computational domain includes all of the North Sea and Baltic Sea, with fine detail in Danish coastal waters. The model was constructed from a depth-integrated, 2-D primitive equation model developed by the Danish Hydraulics Institute (DHI, reviewed later in this article).

DMI, located in Copenhagen, has a small research department for work in atmospheric physics, dynamic meteorology, and oceanography. The Research Department is headed by Dr. Anne Mette Jorgensen; the Meteorological and Oceanographic Research Division in the department is headed by Mr. Leif Laursen. Scientists in this division are upgrading the meteorological model with a HIgh Resolution Local Area Model (HIRLAM). This model covers the Danish mainland and as far west as Greenland, since this also is Danish territory. The Oceanographic Research Division maintains the tide-surge model and is researching improvements. Their work includes assimilating tide gauge data and developing a 3-D model for local area predictions for baroclinic currents and water quality.

Present Tide-Surge Model

It is difficult to accurately predict tides and surges in the seas surrounding Denmark. Processes associated with the surrounding large seas and the complicated bathymetry in the straits and shallow water between them are extremely complex. Because of density differences between the brackish water in the Baltic and the much saltier water in the North Sea, there is significant stratification and variation of the position of fronts in the shallow water in the region of the Danish Great Belt. This stratification is important for water quality issues, because it enables large velocity gradients over the water column. The effect of the stratification is ignored in the tide-surge model, and the water column everywhere is assumed to be vertically mixed—the so-called barotropic assumption. The

2-D, depth-integrated equations of motion, then, are solved with forcing at the boundaries.

The most important forces that drive the currents and changes in water level are the astronomical tides and the forces of wind and air pressure on the surface. The large tidal motions in the North Sea gradually decrease through the Skagerrak, the Kattegat, and the Danish Belt to the Baltic where only small tidal motions occur. On average, however, the salinity of the Baltic is about three times lower than that of the North Sea. Thus, the flow in the relatively shallow transition zone between the Baltic and the North Sea involves density currents, and the flow tends to be very complex.

The primary objective of the warning system is to forecast the water level to provide sufficient warning of high levels for the orderly evacuation of people in low-lying coastal regions. A secondary objective is to provide warning of high currents for construction projects, specifically a very long bridge that is being built across the main shipping channel between the North Sea and the Baltic, called the T-route. The primary requirement could be met by the same type of 2-D, depth-integrated model used by all other countries surrounding the North Sea. The secondary one should use at least a two-layer model for the waters in the region of interest. It was determined[1] that

- a multiple-layer model would be difficult to implement with available computer power and measurements, and
- a single-layer model would be adequate, with the simulated currents being adjusted by monitoring at the construction site.

The required adjustment to provide an accurate forecast would be a linear function of the predicted current magnitude as determined by statistics of the difference between measurements and simulations.

The hydrodynamic model is a subset of models that have been developed by the Danish Hydraulics Institute, with some modifications and enhancements for this application. It solves the momentum and continuity equations in a typical manner,

- with an implicit finite-difference technique on a staggered rectangular grid (Arakawa C-grid), but
- with nontypical nesting of grids having different spatial resolution.

The benthic friction is given by a Chezy coefficient so that the bottom stress is proportional to the square of the water speed and inversely proportional to the square of water depth. The computational domain is an optimal choice that appears to meet their specific needs. The domain includes the whole North Sea and Barents Sea so as to include most larger scale effects. It has artificial boundaries on an east-west line between the Orkney Islands north of Scotland and Stavanger, Norway, and a line across the English Channel between Dover and Calais. It is forced by fixed amplitude and phase of the first 10 measured tidal constituents at these boundaries and adjusted by atmospheric pressure. The grid resolution is 18 km everywhere in the North and Baltic Seas. However, it has a nested 6-km grid in the Skagerrak and Kattegat and a further nested 2-km grid in the Wadden Sea and the narrow, shallow seas of the region of the Great Belt. Each of these two subregions is rectangular in shape. The grids are nested, and the boundary conditions at the interface between them directly link the variables so that full interaction of the flow and water level is maintained. A high value of eddy viscosity is specified in the local vicinity of the interface (six grid points either side) to filter out numerical instabilities that are generated at the boundaries. The time step of the model runs is 10 minutes to retain stability and provide reasonable accuracy. The model runs on a Convex 3880, and the code has not been vectorized. A full 6-day simulation takes about 10 minutes to run.

The meteorological forcing is provided by wind stress and atmospheric pressure data from the operational meteorology model. The wind velocity corresponds to the 10-m level in the meteorological model. The stress is specified by a simple drag formula that is proportional to the square of the wind speed, with the drag coefficint being weakly dependent on wind speed. The atmospheric variables are supplied from the numerical analysis and forecast of the meteorological model, which itself is a nested forecast system.

The global weather forecast system at ECMWF provides the larger scale weather parameters for time periods out to medium range. It also provides the lateral boundary values for a fine-mesh, short-range Limited Area Model (LAM) component of the Danish forecast system. An

earlier model used a Danish LAM, but the U.K. LAM from the U.K. Meteorological Office was recognized as better, and meteorological data presently are obtained from the U.K. This is made available two times daily immediately after the U.K. LAM run in Bracknell.

An even newer meteorological forecast system, the High Resolution LAM (HIRLAM) has been in development since the late 1980s. This was developed by the Nordic countries consisting of Denmark, Norway, Finland, Iceland, and Sweden, and later including The Netherlands.

HIRLAM consists of a numerical analysis technique, an initialization scheme, and a forecast model. The analysis scheme transforms the irregularly distributed global meteorological observations to a rectangular grid with essentially the same technique used by ECMWF, although extended to the limited area version. The technique is an optimum interpolation technique extended to 3-D interpolation of observed deviations from a 6-hour orecast field from the previous analysis. The initialization scheme balances the analyzed fields to remove high-frequency gravity waves. It does this by using a nonlinear normal-mode technique with four vertical modes started with adiabatic tendency and iterated twice. Finally, the forecast model solves the primitive equations with a quasi-hydrostatic approximation in the momentum equations, conservation of mass, and the energy equation. Again, the horizontal grid has rectangular spacing with Arakawa C-grid location of variables and semi-implicit time steps. The coordinate system is a rotated spherical system with the pole moved to the subtropical North Pacific so that the appropriate part of the Northern Hemisphere is well-resolved. The numerical model is actually run on two separate limited areas. A small-area version called DKV LAM (0.21-degree resolution) is nested in a larger area version called GRV LAM (0.42-degree resolution). Both models run with 31 sigma-pressure hybrid levels in the vertical, using the boundary and initial values of the solution from the next larger grid. ECMWF data are used for the GRV LAM run, and GRV LAM data are used for the DKV LAM run. Surface processes are optimized by using a "fraction of land" or "fraction of ice" formula in locations that span land, ice, or water. Reference 2 provides more details on HIRLAM; it can be obtained from DMI directly (address provided below).

The determination of the surface wind is critically important, so special attention has been given to this calculation. The wind speed that is provided for the surface stress on the water is obtained from a parameterization of the vertical turbulent flux of momentum in the atmospheric surface layer. The prognostic variables of the atmospheric model are temperature, velocity, and specific humidity at many levels (the lowest of which is 35 m above the model terrain). The lowest level data are used with the similarity theory of Monin and Obukhov to estimate a drag coefficient and therein the wind speed. This formulation includes the effect of stability on the vertical profile of wind speed through the Monin-Obukhov length parameter and the Charnock formula for surface roughness over the sea. This parameterization is typical, but it would be interesting to see how well this really works by a verification experiment in such a complicated coastal area as Denmark.

The actual operational runs for the tide-surge model are made at 0300 and 1500, immediately after the meteorological forecast run. The software is installed on a Convex 3880 mini supercomputer. Each run consists of a 24-hour hindcast, a 36-hour forecast with the U.K. LAM data (in parallel with the HIRLAM model at present, as noted above), and a 120-hour forecast with ECMWF data.

The model has been fine-tuned by comparing the predictions with specific measurements and slightly modifying some of the parameters. The tidal amplitudes and phases that are specified at the boundaries, for example, have been modified slightly to improve simulations of the tides at stations along the Danish coast. Also, the coefficients in the wind drag and bottom drag have been modified slightly, but the standard values appear to give reasonably good results in tests with hindcasts of some of the larger storms.

The storm tide warning service provides the operator a monitor display of a time series plot of the predicted water level at several locations along the coast, as well as the measured water level at these locations up to the present time. Also, it displays a curve representing a "statistical"

prediction based on an optimal interpolation of the data. They obtain reasonably good results with stated errors of about 10 cm (although there was an overshoot of the model of about 30 cm above the forecast value of high water during a significant surge that occurred while I was observing the system in operation). There apparently are minor problems associated with external surges that enter the North Sea along the Scottish coast and propagate all the way down the east coast of England and around the Dutch and German coasts to the Danish coast. Again, the errors are stated to be order of 10-20 cm, but apparently these external surges cause only minor elevation changes on the Danish coast. A larger problem concerns the accuracy of the meteorological model for surges generated entirely in shallow Danish water by storms that are smaller but very energetic. The HIRLAM model is designed to solve this problem.

The model also is used to provide warnings for high surface current velocity in the vicinity of the bridge project. Because the model does not resolve the important vertical structure of the velocity profile, the predictions are coupled with local water velocity measurements. The local measurements are made with two Acoustic Doppler Current Profilers, and an effective surface current is estimated from the profiles. Then, the measured surface current values are correlated with the simulated currents by one of three procedures so that a prediction can be made for the expected currents in the near future:

- One estimator is a linear regression between the last 30 hours of data and simulation velocities.
- A second one is simple extrapolation where the most recent local measured value is summed with the simulated value.
- The third technique is a Kalman filter where the forecast is a sum of the simulation (with gain estimated from previous data), the most recent measured value (with exponential memory), and a moving average of the most recent measured values. (This is similar to a technique published by Harrison and Stevens.[3])

The actual forecast is made from a study of these three estimates and a lot of operator experience.

Research on Improvements

Dr. Jakob Nielsen and Dr. Karsten Holding are quite familiar with the surge model, and they briefed me on it. They are responsible for hindcasting any problems that occur. They were especially busy during my visit to DMI because there was a strong storm in the North Sea and a high surge forecast for that day. They feel that improved resolution in the meteorological model is most important for improving the forecasts; they believe that HIRLAM will accomplish this; and they are presently involved in evaluating the model. They were reluctant to provide hard numbers, but they evidently were impressed with the new model.

The oceanographic group also is working on two other projects that are expected to improve the model in the future. The first project is assimilation of tide gauge data by the model, which is being pursued by Dr. Ole Brink-Kjaer. This follows the suggestion of the Dutch[4] and apparently has been applied successfully at the Royal Netherlands Meteorological Institute. He is not sure that it will help as well in the Danish case because of the reduced effect of waves propagating into their waters from "upstream" in the North Sea. They are pursuing this methodically, carefully evaluating a Kalman filter technique; results are not expected for a year or more. They presently get tide data from several British locations in near realtime, but data from other countries are not readily available. A case can be made for having this type of data available from all reporting stations in near realtime, just like the meteorology data are available on the Global Telecommunications System (GTS) of the World Meteorological Organization (WMO).

A three-dimensional circulation model is being developed by Dr. Julie Pietrzak. The goal of this work is to resolve baroclinic currents that are important for the bridge-building problem. But they really are looking more toward the future where water quality issues in the highly stratified water are expected to be of concern. She does not feel it will improve the surge forecasts because of

the small impact of the stability of the water column in the shallow seas on the overall results for water levels.

Discussion and Conclusions

This small but young and energetic research group is focusing its efforts on several projects that they expect will improve the accuracy of their coastal prediction system. The 3-D work is supported at the two-man-year level. It shows preliminary signs of developing into a useful product, although the specific requirements are ecological in nature, and they have not been made very specific to date.

The present circulation model does not seem to have been exercised to the fullest. Dr. Anne Mette Jorgensen has written a summary article with co-authors from DHI recently,[5] but they do not seem to have fully tapped its capabilities. In particular, although the model domain includes the whole Baltic Sea (the only operational model to do so as far as I am aware), they have not worked with their eastern neighbors on its verification. Model results surely are of value to these countries, if only for research purposes.

This group has several international projects of interest. They provide the meteorological data to the Greenland Sea Project, which is researching overturning of the water column and generation of deep water by chimneys. Also, they are a member of a team working up plans to establish a Global Water Exchange Experiment (GEWEX) program in the whole Baltic Sea drainage basin.

In common with several other oceanographic research groups associated with operational forecasting in northern Europe, this group has many European contacts but practically none in the U.S.

In conclusion, Denmark has a unique problem with their extremely complicated bathymetry of the shallow seas and sill between the Baltic and Northern Seas. Their progress, or lack of it, in the next few years is of unique and potentially valuable interest.

DANISH HYDRAULICS INSTITUTE

The Danish Hydraulics Institute (DHI) is a nonprofit coastal engineering research and development firm that is pursuing several projects of interest. They have developed the Danish tide-surge model that is implemented at the Danish Meteorological Institute (DMI), and it is unique because the model is solved on a nested grid.

They are working on a 3-D circulation model for the complicated bathymetry and circulation in the narrow, shallow, highly stratified seas called the Danish Belts in the east of Denmark. They have direct competition with DMI and the Institut fur Meereskunde in Kiel in this area, with the latter being especially strong.

Like many research institutes, there is too much here to review in a short visit. They have much in common with the other strong hydraulics institutes in northern Europe and have many contracts both within and outside the EC. They also have small-scale physical models for harbors (large wave tanks), with much experience in instrumenting them and comparing the effects of construction options on the resulting wave climate. One of the large wave tanks is used for simulations of 3-D waves for studies of mooring motions of large offshore platforms and for measurements of ship motions. They are using the latter measurements to verify a new technique they are developing for calculating the nonlinear response of a ship to the seaway.

Hydrodynamic Model MIKE 21

This is a comprehensive modeling system for 2-D free-surface flows where stratification can be neglected. The model has numerous modules that perform particular calculations for various applications. A module called MIKE 21 HD performs the basic hydrodynamic calculations. It solves the depth-integrated primitive equations of motion, i.e., the momentum and continuity equations, by a typical finite-difference method on a grid of points. The specific technique is identical to other layer models, and it includes the effects of wind and bottom stresses by using drag coefficients, with no special turbulence closure scheme. A module called MIKE 21 WA calculates the spectrum of surface waves; MIKE 21 ST calculates sediment transport and the rates of bed level changes in coastal areas subject to the action of waves and currents.

This is the primary subject of interest to the laboratory, so the effort has been stronger in this area than in the waves or circulation areas. The

objective is to assess erosion or deposition around large coastal engineering structures such as beach protection structures. The sediments are assumed to be noncohesive, i.e., sand, with a grain size that may vary over the computational domain. The currents and water depth are first calculated by the HD module, then by the wave field; finally, the erosion and deposition rates are calculated by the ST module. The basis of the transport calculations is a model for turbulent wave-current boundary layers.[6] The module uses a catalog of rates that have been directly measured by DHI or published by others in the past. It calculates the rates for the local conditions and iterates with the HD module to calculate the effect of the bathymetry changes on the waves and currents. Graphical output is the temporal history of the 2-D bathymetry for the region under study. This module is known to be accurate only for medium or coarse sand. Additional work is underway to extend to finer grain and cohesive sediments. Model verification remains a problem.

One or more subsets of the MIKE 21 model have been sold to more than 300 customers. DHI provides training and consultative services on implementation of the model to user needs. One successful project has been with Bangladesh, where a huge expanse of low-lying land is periodically flooded. The very complicated channels of the delta have been successfully modeled but, again, little specific verifications have been done to date.

In another example, DHI is working with an Italian syndicate to model the effects of civil engineering constructions. These are associated with the Vienna project that is designing and building defenses against water level surges in the Adriatic Sea. For example, DHI has a model of the whole Adriatic, although they do not have real-time forecast winds to run it operationally. They also have wave models and littoral drift models for studying the effects of seawalls and movable barriers. The MIKE 21 circulation model used 300-m resolution in the Venice lagoon, with 100-m nested modules in the vicinity of the three entrances. The results, then, were used to predict modifications in sediment transport.

Other Hydrodynamic Models

The operational tide-surge model run by DMI is a modified version of the MIKE 21 HD module. The grid is interesting because of the specific manner in which sub-grids are embedded (as explained in the accompanying article on DMI); otherwise, this research model is identical.

DHI is developing a 3-D circulation model for future use in water quality issues. However, they have not done much more than verify that it provides reasonable solutions for special simple cases that have exact or approximate solutions. An example of a lock experiment has been tested, and the advection scheme found wanting, so this is being upgraded.

They have formed several relationships that enable them to compete in other arenas. They own part of Arctec Offshore Corporation in San Diego, CA, providing an opening for U.S. markets. They also have a joint department for development of a water quality model with the Danish Environmental Institute, which is located across the street from them.

This laboratory has been highly successful in attracting projects in the international market, accounting for some 90% of their work. Its competition are the other European hydraulics laboratories—the Dutch (at Delft), the U.K. (at Hydraulics Ltd), and the Norwegians (at SINTEF), and it seems to be holding its own quite well.

THE GEOPHYSICS INSTITUTE, UNIVERSITY OF COPENHAGEN

Two scientists of special note are at the Geophysics Institute of the University of Copenhagen: Prof. Aksel Wiin-Nielsen and Dr. Niels Hojerslev. Professor Wiin-Nielsen is widely respected for his long career at the National Center for Atmospheric Research in Boulder, Colorado, the University of Michigan, and as head of DMI, but most notably as the first director of ECMWF, an institute we highly respect. He has a few interesting ideas that must be mentioned. First, he has an abiding interest in coupled models of the ocean and atmospheric

boundary layers in the coastal zone, and would like to see what the Office of Naval Research can do in cooperation in this area. He believes a project in this area could get significant EC funding for the Danes and other Europeans if there were an international aspect, and he is willing to help organize such an effort. He is especially interested in organizing a workshop of leading European researchers if ONR would be interested. In the past, this office has had finances for such meetings, and this one would be highly recommended. Professor Klaus Hasselmann of the Max Planck Institute for Meteorology in Hamburg also is thinking these same thoughts.

A second point is that Prof. Wiin-Nielsen was instrumental in coaxing the three former Danish meteorological organizations (DMI, the civilian airport authority, and the military) into one more-efficient and much-better organization (that is now DMI). We might study his success in this as a possible model for emulation in the U.S.

Dr. Hojerslev is the successor to Profs. Jerlov and Kullenberg for ocean optics research at the Geophysics Institute, and he has interesting work going on in modeling and measurements of optical properties of seawater. He has several advanced students for whom he is trying to find posts outside Denmark and asks for possible ideas. Also, he is interested in cooperative research with U.S. researchers who are using the NASA SeaWiFs system. His group seems to be a good candidate for collaboration with U.S. projects because he already has basic salary support for himself and students. He needs only data.

Between Prof. Wiin-Nielsen and Dr. Hojerslev, they have several good ideas that appear worth pursuing for possible collaborative research at little or no cost to the U.S., and a follow up should be considered.

REFERENCES

1. M.B. Abbott, A. McCowan, and I.R. Warren, "Numerical Modelling of Free-surface Flows That Are Two-dimensional in Plan," in *Transport Models for Inland and Coastal Waters* (Academic Press, London, 1981) pp. 222-283.
2. B. Machenhauer, ed., "HIRLAM Final Report," HIRLAM Technical Report No. 5, DMI, Copenhagen, Dec. 1988.
3. P.J. Harrison and C.F. Stevens, "Bayesian Forecasting," *Journal of the Royal Statistical Society, Series B*, **38**, 205-247 (1976).
4. A.W. Heemink and H. Kloosterhuis, "Data Assimilation for Non-linear Tidal Models, *International Journal for Numerical Methods in Fluids* **11**, 1097-1112 (1990).
5. H.J. Vested, H.R. Jensen, H.M. Petersen, A.-M. Jorgensn, and B. Machenhauer, "An Operational Hydrographic Warning System for the North Sea and Danish Belts," *Continental Shelf Research* **12**(1), 65-81 (1992).
6. J. Fredsoe, "The Turbulent Boundary Layer in Combined Wave-Current Motion," *Journal of Hydraulic Engineering-ASCE* **110**(8), 1103-1120 (1984).

Contacts

Danish Meteorological Institute
Mr. Leif Laursen
Chief, Meteorological and Oceanographic Research Division
Lyngbyvei 100
DK-2100 Copenhagen 0
Phone: +45 3915 7500
Fax: +45 3927 1080

University of Copenhagen
Professor Aksel Wiin-Nielsen
Institute of Geophysics
Haraldsgade 6
Copenhagen N, DK-2200
Phone: +45 35 32 06 06
Fax: +45 35 82 25 65

Danish Hydraulics Institute
Dr. Ross Warren
Head of Computational Hydraulics Centre
Agern Alle 5, Horsholm, DK-2970
Phone: +45 45 75 95 55
Fax: +45 45 76 25 67

FEDERAL REPUBLIC OF GERMANY

INTRODUCTION

Many organizations in Germany have work associated with operational models or strong research and development associated with improving them. The Institut fur Meereskunde at the University of Kiel (IfM Kiel) and the Institut fur Meereskunde at the University of Hamburg (IfM Hamburg) both have significant modeling research and development efforts for oceanographic models. The Max-Planck-Institut fur Meteorologie at the University of Hamburg (MPI) also has a significant involvement in model development, led by by one of its directors, Professor Klaus Hasselmann. The Bundesamt fur Seeschiffahrt und Hydrographie (BSH) provides forecasts to the user community; it runs some developmental and operational models, while the German Weather Office (DWD) actually runs the models. The Meteorologie Institut at the University of Hamburg also performs research in meteorological models. This report reviews and assesses work of IfM Kiel, IfM Hamburg, MPI, and BSH.

INSTITUTE FUR MEERESKUNDE, UNIVERSITY OF KIEL (IfM Kiel)

The Institut fur Meereskunde at the University of Kiel (IfM Kiel) is a leading oceanographic research institution in Germany. It has strong departments in all aspects of oceanography and marine meteorology, with many of the departments headed by internationally known senior scientists. Several groups are involved in research in physical oceanography. The Theoretical Department is headed by Prof. Wolfgang Krauss; the Regional Oceanography Department is headed by Prof. Fritz Schott; and the Ocean Physics Department is headed by Prof. Gerhard Siedler. The Theoretical Oceanography Department has had long experience in numerical models of ocean processes.

Of some interest are projects on modeling flows around large-amplitude topographic features (seamounts in particular) and a model for the general circulation of the North Atlantic Ocean, but the work that gets our attention involves a model for the circulation of the Baltic Sea. This topic is especially appropriate for review here because it is associated with shallow water.

Even though the Baltic Sea is large (approx. 4×10^5 km^2), it has an average depth of only about 50 m, so it practically all has to be considered shallow water. The deepest basins are only slightly more than 300 m. Except for the northernmost one (the Bothnian Basin), the fresh water inflow from the rivers causes strong enough vertical stratification that the strong surface cooling in the winter is not able to overturn and renew the deep water in the basins. Thus, the renewal must come from the much saltier water of the North Sea. Until January 1993, this had not occurred since the winter of 1976. Then, strong westerly winds from a period of storms pushed North Sea water through the Danish Belts. It crossed over the sill (only 17 m deep) and spilled down the slope into the basins. The long time of 17 years between renewals has permitted biogeochemical processes to reduce the deep water to anoxyia, a condition of major ecological concern. This renewal process needs to be better understood.

Also, even though numerous observations have been made of the 3-D structure of the density and velocity fields over time, we do not understood why the mesoscale field is so highly energetic. These and other questions can only be answered by running experiments with a model that includes the appropriate dynamical processes.

Baltic Circulation Model

Dr. Andreas Lehmann just finished his Ph.D. under Prof. Krauss, and he is continuing the development of a circulation model of the Baltic Sea that he began as his thesis topic. This is a Bryan-Cox model, modified to include a free surface. The computational domain includes the whole Baltic, the Danish Belts, the Kattegatt, and the Skagerrak out to a meridional line from the north end of Denmark to Norway where there is an artificial boundary. The North Sea is represented by a simple reservoir, and the temperature and salinity are fixed to observations on the common boundary. The effect of fresh water influx from the rivers also is represented by fixing the value of salinity to observations at the location of the river mouths. There is no model for the ice that forms during the winter months in the northern part of the Gulf of

Bosnia. The model has 12 fixed vertical levels and 5-km horizontal resolution. The topmost four levels each have thicknesses of 6 m, so the vertical resolution is reasonably good for the surface layer including regions of relatively shallow water.

Motions are caused by both thermohaline forces in the interior and by atmospheric forces at the surface. The atmospheric forcing includes the synoptic (3 hourly) surface pressure fields as analyzed by the German Weather Service in Offenbach. The surface wind is estimated by geostrophic balance with a correction for turning and magnitude reduction in the boundary layer. Then, the stress is estimated by using a drag coefficient formulation using the observations of Large and Pond. The model run is started from rest with smoothed observations of the density field. This field was obtained from an objective analysis of data from many years of measurements for the month of October assembled by the former Deutsche Hydrographische Institut (now BSH). After a spin up time of 60 days (by which time the kinetic energy has settled down to a constant value), the wind is turned on and the model run for an additional year. The model run that I saw was for 1989. The data exhibit the expected wind-driven currents and very good temperature and salinity fields. The latter fact is very encouraging since there is no "nudging" to climatology to prevent the results from "running away" from reality. Also, the data exhibit considerable mesoscale variability, just as observed from in situ measurements and satellite images.

Several particularly interesting results have been found to date. The solutions can be verified in this case by comparing simulated water levels with tide gauge measurements. Predicted water level fluctuations were found to be in phase with measurements, but they were found to be low by a significant fraction. Thus, the drag coefficient in the surface stress calculation was tuned, and good agreement was obtained with a value 50% higher than Large and Pond. This is much higher than can be accounted for by experimental error, but the agreement with measured water levels is very convincing. The reason for this difference is still being studied.

Also, the simulated near-surface velocity agrees very well with Acoustic Doppler Current Profiler data that were measured with an IfM Kiel instrument in water of 20-m depth in the Danish Belts. The few events having large differences could be explained by occasions where there was a major shift in the wind, apparently due to the passage of a front, and the simple procedure for estimating the wind at the surface used in the model accounts for this type of error. In addition, the structure of the numerous coastal jets and filaments in the simulation are very much like those seen in satellite images of the surface temperature, although there are no direct verifications of the resulting velocity and density fields.

Planned upgrades for the model include improving the procedure for approximating the fresh water input from the river discharge, adding an ice model for the northern basin, introducing passive tracers (and perhaps model equations for biological processes), and improving the representation for the North Sea.

One planned investigation with the model is a study of the eddy dynamics, including the effects of Kelvin waves, involved in the fluctuations along the coasts. Also, tracers will be incorporated into the model to study the overturn time of the deep water, including processes associated with injections of salty water from the North Sea. Dr. Lehmann hopes to make more detailed comparisons with observations.

Other Associated Modeling Programs

Two other modeling efforts at IfM Kiel are noteworthy. They are important in their own right, but they also improve the position of the work on the Baltic model by their impact on the overall size of the group involved in the specific activity of 3-D ocean modeling.

Dr. Aike Beckmann is attempting to model the flow around large-amplitude bathymetric features such as seamounts. He has constructed a regional model based on practically the same model as Dr. Lehmann. He is is a member of a small group that includes Dr. Dale Haidvogel of Rutgers University and Dr. David Chapman of the Woods Hole Oceanographic Institution, who are working on this problem. In the U.S., this program is called TOPO. This modeling work with Dr. Haidvogel also involved earlier simulations of the formation of filaments and their evolution in the coastal

transition zone in a former ONR program of that same name.

In addition, both Dr. Beckmann and Dr. Klaus Boning of this Department are working as part of a Community Modeling Effort to understand the global ocean circulation, its variations, and its effect on our climate. They have run the National Center for Atmospheric Research (NCAR) ocean model for the North Atlantic at as high as 1/6-degree resolution for a 5-year simulation (2500 hours of Cray X/MP time). They have also run a number of experiments testing the effects of different friction, resolution, boundary conditions, and forcing.

This clearly is the leading circulation model for the Baltic. This is an excellent research tool, and it can serve as a basis for planning new series of observations. One opportunity to do this could be an upcoming program that is proposed to begin in the coming year. IfM Kiel, together with other institutes of the Baltic countries, is planning a multi-year experiment as part of the international program Global Energy and Water Cycle Experiment (GEWEX). This experiment, called BALTEX, includes an area covering the whole drainage basin of the Baltic and the Baltic Sea. IfM Kiel is in an excellent position to be the lead institute for the ocean modeling component of this experiment.

Professor Krauss has given a copy of an earlier version of the model to Finland, but they have not generated the effort that is required to get it running. He also notes that Sweden has plans for a model, and he knows about the Danish work (reviewed here). He believes that Russia, the smaller Baltic states, and Poland are not even in the starting gate, so there is no real competition in this area. By default, it will be the lead candidate for oceanographic modeling in the planned GEWEX program.

INSTITUT FUR MEERESKUNDE AT UNIVERSITY OF HAMBURG (IfM Hamburg)

The Institut fur Meereskunde at the University of Hamburg (IfM Hamburg) is a research branch and department of the University of Hamburg. It has close cooperation with the nearby Institutes of Meteorology, Geophysics, and Geology; the Max-Planck-Institute of Meteorology; the German Hydrographic Institute; and the GKSS. For some years, research at IfM Hamburg was dominated by the modeling of Dr. Backhaus, but it has expanded in recent years with the addition of Prof. Meincke from IfM Kiel (observations of ocean physics) and Prof. Werner Alpers from the University of Bremen (remote sensing) and their experienced research staffs. IfM Hamburg has Departments of Regional Oceanography, Ocean Physics, Remote Sensing, as well as other disciplines.

Circulation Modeling

Professor Jan Backhaus was not present during my visit, so we have no up-to-date assessment of IfM Hamburg's circulation and storm-surge modeling. It is rumored to be strong.

Remote Sensing Research

Professor Alpers' group is involved in research and development of techniques for remote sensing of the ocean by using active microwaves, including scatterometers, synthetic aperture radar (SAR), and altimeters. In the scatterometer and SAR cases, they are involved in the analysis of both aircraft and ERS-1 data. Part of this is basic research on scattering physics, part on use of the technology for studying ocean physics, and part on use of the data for assimilation into ocean prediction systems.

The strong influence remains of Prof. Hasselmann of the Max-Planck-Institute for Meteorology, which also is located at the University of Hamburg (but some distance away). Hasselmann maintains his strong interest in wave mechanics and stays in close contact with research in this group. He was the theoretical force behind modeling of the transport equation and the nonlinear energy transfer mechanics for the surface wave spectrum. He remains a spiritual leader of the WAM group (discussed in Netherlands review).

Dr. Claus Bruning is using a transfer function that was a group effort by Drs. Bruning, Klaus Hasselmann, and Susanne Hasselmann to estimate the 2-D wave spectrum from the 2-D cross-section spectrum from the ERS-1 SAR data. The algorithm for doing this must be very efficient. The cross-section spectrum is obtained from the satellite every 200 km along the track interlaced with scatterometer data when it is in that mode, therefore retaining a high number of data sets. The inversion algorithm uses the spectrum from the WAM model

that is run at ECMWF to provide the first guess in a linearization and iteration scheme to calculate an improved wave spectrum. In a real sense, although untypical, this can be considered a data assimilation scheme. This has had impressive initial results, with a surprisingly high number of cases with multiple spectral peaks. One interesting result is the absence of an apparent universal spectrum at sea.

Also, since it is recognized that the wave spectrum is so dependent on the history and distribution of the wind field, Hasselmann feels that the data obtained from the SAR must contain sufficient independent information to recalculate the wind field. This is very important because, in his view, the weakest link in the assimiltion of satellite data in ocean forecasting (waves, circulation, surges, and lower atmosphere) is the accuracy of the wind data. This is being pursued by Dr. Eva Bauer in Alpers' group, by assimilating altimeter-derived wave data into the WAM output. The objective of the work is to investigate the consistency of satellite-derived wind and wave data by using the third-generation wave model. An additional goal is to investigate ways to assimilate the wave data into the model. This cross validation of data types is a recurring element of Hasselmann's work. Types of data that are available include scatterometer-derived winds, altimeter-derived significant wave height, and SAR directional wave information. The impetus is provided by the needs of operational systems for both the wind and waves information. This work also is yielding encouraging results, and is expected to provide the basis for a data assimilation scheme for improved winds as well as waves.[1]

MAX-PLANCK-INSTITUT FUR METEOROLOGIE (MPI)

The Max-Planck-Institut fur Meteorologie (MPI) is the leading German institution for research in climate change. Its senior professors include a number of world-class researchers, with Dr. Klaus Hasselmann being the one of interest in this report. The Institute is closely associated with several other institutes in the area. It is collocated with the Institut fur Meteorlogie that is a department in the University of Hamburg, and they share facilities and students. These two are in the same building as the Joint Climate Computing Center (DKRZ) that is the leading German computing facility (they have a Cray II, a Cray Y-MP, and a Convex 220, so they do not suffer lack of computing power). Also, the Institut fur Meereskunde (IfM) at the University of Hamburg (discussed above) has some closely aligned interests, and it is located but a short distance away.

MPI has a permanent staff of about 45, with another 50 students and researchers on contract. The total budget is about DM 40M per year, with 6M for MPI staff, another DM 6M for university staff, about 10M soft money, and DM 18M for the computing facility.

Hasselmann's Group

Hasselmann's group is primarily involved in modeling the climate and its variations, and they specialize in coupled ocean-atmosphere models. Researchers have made calculations of the effect of climate change on the rise in sea level, with a recent seminal paper on this subject.[2] It addresses the effects of regional changes in level due to regional changes in the distribution of ocean mass.

Proposal for Coupled Model

Dr. Hasselmann has proposed European Community Marine Science and Technology (MAST II) Programme support for a new project on the development of a coupled meteorology-waves-ocean model. The politics of these proposals are ferocious, and this apparently was rejected because MPI already had significant research progressing in this area. The idea behind the proposal is outlined in the following paragraphs because it has much merit, and it perhaps could be considered for support in some form in the U.S. The proposal is called ECAWOM (Development of European Coupled Atmosphere-Wave-Ocean Model and Data Assimilation System for Application in European Seas, although, of course, the idea applies elsewhere).

Briefly, the goal of the project is to integrate a number of ongoing efforts in several European institutions to produce a new joint state-of-the-art European Coupled Atmosphere-Wave-Ocean Model. The model then could be used as a common tool for studying improved physics and numerics and for a wide variety of applications. Hasselmann

hopes to coordinate ongoing efforts in the use of satellite data to derive wind and wave fields and to use these data together with conventional data in models. Specifically, to use existing atmospheric (HIRLAM), wind wave (WAM, cycle 4, which includes the Janssen stress description) and ocean models, but to concentrate on a consistent coupling between the atmosphere and the ocean through a detailed description of the interactions at the moving interface. The coupling tasks are in sequence:

- WAM and HIRLAM
- WAM and Storm-Surge Model
- WAM and 3-D Ocean Circulation Model
- Development of complete coupled model system

At each stage, extensive validation efforts are to be made by collaborating institutes. The original proposal had 16 subscribing institutes; most of them have been discussed elsewhere in this report.

FEDERAL MARITIME AND HYDROGRAPHIC AGENCY (BSH)

The Deutsche Hydrographie Institut (DHI) has been renamed the Bundesamt fur Seeschiffahrt und Hydrographie (BSH), or Federal Maritime and Hydrographic Agency, to effect changes that more closely support their customer base. Dr. Klaus Huber is head of waves and current research in the Oceanography Division. He has operational systems for waves, water level, and currents that are actually run by the German Weather Office (DWD), and R&D programs to upgrade these systems. Dr. Karl Richter heads the waves group. Their operational model is a second-generation WAM that has embedded grids from the North Atlantic (150-km resolution), North Sea (30-km resolution), and coastal zone (16-km resolution). The meteorological input is the DWD meteorological LAM with 0.5-degree resolution. They are generally happy with the waves model. However, the meteorology misses the shadowing and other shallow-water effects they often see in their realtime data from many platforms and buoys so they still make manual adjustments before providing the forecasts. In addition, the model missed the large waves that the Polish ferry ran into this past winter (and capsized) by a factor of two (6-m actual significant waves versus 3-m forecast). This was primarily because of poor wind representation in the meteorological forecast data. They are discussing future work on assimilation of satellite data but have no R&D to date. Wave model research presently is performed at GKSS Forschungszentrum Geesthacht BmbH by Dr. Rosenthal.

Dr. Stephan Dick developed and runs the operational circulation model. It is a 3-D primitive equation model with free surface on three interactively coupled embedded grids; 40-km resolution in the North Atlantic, 20-km resolution in the North Sea, and 10-km resolution in the German Bight and Western Baltic. It has 10 layers and is driven by synoptic weather from DWD in Offenbach, tidal coefficients, and external surges from a 2-D model of the whole North Atlantic. It provides 20-cm rms accuracy in water level (equivalent to other North Sea 2-D models that do not use data assimilation), and order 10% on currents in the shallow Danish Belts. The model starts from rest with German hydrographic (climate) data, but uses no nudging or data assimilation over 4 months. It does not appear to run away, generating realistic-looking temperature, salinity, and water velocity fields. However, there has been little verification except for water levels and currents in a few places. The model is run daily with meteorological data to provide forecasts out to 48 hours; these are manually adjusted before warnings and advisories are provided for water level and currents.

The 3-D circulation model has a component for simulating dispersion processes. It is used for search and rescue and for calculations of dispersion and drift of oil and soluble chemicals. It is similar to the EUROSPILL model that tracks multiple particles and, therefore, includes estimates of sinking rate, beaching, and deposition.

CONCLUSIONS

These institutes have strong modeling capability for the North and Baltic Seas. It is surprising that so little transfer of knowledge and operational data occurs between Germany and the other European countries. Of all the institutes in Northern Europe, BSH clearly has the best operational circulation model for the Baltic Sea, while IfM Kiel has the best research circulation model.

REFERENCES

1. E. Bauer, S. Hasselmann, K. Hasselmann, and H.C. Graber, "Validation and Assimilation of Seasat Altimeter Wave Heights Using the WAM Wave Model," *Journal of Geophysical Research* **97**(C8), 12671-12682 (1992).

2. U. Mikolajewicz, B.D. Santer, and E. Maier-Reimer, "Ocean Response to Greenhouse Warming," *Nature* **345** (6276), 589-593 (1990).

Contacts

Bundesamt fur Seeschiffahrt und Hydrographie
Dr. Klaus Huber
Bernhard-Nocht-Strasse 78
Postfach 30 12 20
Hamburg 36, D-2000
Phone: +49 (0)40 3190 3100
Fax: +49 (0)40 3190 5032

Institut fur Mereskunde, University of Kiel
Professor Wolfgang Krauss
Head, Theoretical Oceanography Department
Dustenbrooker Weg 20
Kiel 1, D-2300
Phone: +49 431 597 3800
Fax: +49 431 565 876
Omnet: IFM.KIEL

Institut fur Meereskunde at the University of Hamburg
Prof.Dr. Werner Alpers
Troplowitzstrasse 7
Hamburg 54, D-2000
Phone: +49 (0)40 4123 2605
Fax: +49 (0)40 4123 5713
Omnet: IFM.HAMBURG

Max-Planck-Institut fur Meteorologie
Dr. Klaus Hasselmann
Bundestrasse 55
Hamburg 13, D-2000
Phone: +49 (0)40 411 73236
Fax: +49 (0)40 411 730
Omnet: MPI.METEOROLOGY
E-mail: klaus.hasselmann@dkrz.hamburg.dbp.de

BELGIUM

UNIVERSITY OF LIEGE

Professor Jacques C.J. Nihoul is chairman of the GeoHydrodynamics and Environment Laboratory in the Department of Physics at the University of Liege. He also is chairman of the Department, and has a long history in developing ocean, coastal, and estuarine models with his many students. He also has been the organizer of many meetings, and annually hosts the Liege Colloquium on Ocean Hydrodynamics that often has been sponsored by ONR. For example, this spring was the 25th annual meeting, and the timely topic was Data Assimilation; last year it was Sub-Mesoscale Air-Sea Interactions. He also founded and edits the *Journal of Marine Systems*, at least in part to provide an editing and reviewing procedure for publishing the proceedings of the Colloquia. This publication is unique because it really is the only academic journal devoted to interdisciplinary oceanographic modeling research.

As might be expected, Prof. Nihoul also has some interesting new developments, particularly in the area of 3-D modeling. He has a scheme for dynamical analysis of archived oceanographic data whereby they are analyzed consistent with a dynamical model. The available observations are first mapped and used to estimate geostrophic currents. These are then used iteratively to obtain a better analysis of the observations. He calls this an inverse method, and it has two unique aspects. The first is a method to calculate the geostrophic currents in water of varying depth; the second is a nonisotropic mapping function whereby the cross-stream correlation scales are much shorter than those alongstream. This seems to have worked well along coastlines and steep bathymetric features. It has been applied to the summer Bering-Chukchi Seas and the Western Mediterranean. The northern latitude work was associated with the U.S. National Science Foundation's ISHTAR (Inner Shelf Transfer and Recycling) Program and the Mediterranean work with the EC EROS 2000 (European River Ocean System) Project.

Professor Nihoul and Dr. Jean-Marie Beckers also exercise sigma coordinate 3-D models for both the North Sea and the Western Mediterranean in

work is a proving ground for the models that are implemented for the operational forecasts by MUMM, the Belgian government agency responsible for such ocean forecasts.

MANAGEMENT UNIT OF THE NORTH SEA MATHEMATICAL MODELS (MUMM)

An outgrowth of Prof. Nihouls' laboratory is a government unit called MUMM (Management Unit of the North Sea Mathematical Models), which is headed by Dr. G. Pichot, a former student and colleague at the University of Liege. This unit is responsible for maintaining and running operational models and also for monitoring coastal waters. For the latter, they use a small research vessel (750 tons) and a small aircraft for remote sensing. They have operational systems for waves and storm tides and a dispersion model for oil spills, dredge spoil, and pollution dispersion. They also have an algae bloom ecological model, which was developed by Prof. Billem, Department of Microbiology of the Marine Environment at the University of Brussels.

The storm surge model is called MU Storm. This model solves the 2-D shallow-water equations with a nested grid of 30 km in the northern North Sea and 6 km in the vicinity of the Belgian coast. The forcing is by eight tidal constituents along the boundaries of the North Sea and wind stress and air pressure fields from the U.K. Meteorological Office fine-grid weather forecasts. They use the latter because of their uniquely good spatial resolution and accuracy, in their opinion, but apparently based on some limited analyses. They get the weather data from the Belgian Meteorological Institue in Brussels, and they make twice per day forecasts out to 36 hours, with a 6-hour total delay. Forecasts and alarms are provided for high water, pollution, and blooms.

The wave model was described by Dries Van den Eynde. The wave predictions are made by using a hybrid parametric shallow-water wave model (HYPAS) developed by GKSS in Offenbach in Germany (Drs. W. Rosenthal and H. Gunther). This is a second-generation wave model that combines the traditional approach of independent calculation of swell energy for each frequency and direction through a ray technique. It uses a parametrical wind sea model and the parameters of the JONSWAP spectrum and the mean sea direction as prognostic variables. Shoaling is included, but not wave dissipation in shallow water. The grid resolution is 50 km over most of the North Sea, with a fully coupled nested region of 10-km resolution in the southern part. The spectrum is represented by 20 frequency and 24 direction bins.

For extrapolation into very shallow water, the model also has a ray tracing algorithm for backward extrapolation of the refracted wave energy for the entrances to Zebrugge and Antwerp. This algorithm uses 500-m resolution, and depths are provided from MU Storm. This is stated to be the only shallow-water wave-prediction system in operation on the North Sea. They feel the accuracy is limited only by the accuracy of the wind fields that are provided. The model output is used as a management tool for ship routing for the Belgian harbors and the shallow sea along the coast and also for dredging operations. The data are used for low-frequency waves in the same way as the RWS in The Netherlands.

Contacts

University of Liege
Professor J.C.J. Nihoul
GeoHydrodynamics and Environment Research Laboratory (GHER)
Sart Tilman B-5
Liege, B-4000
Phone: +32 4 156 3350
Fax: +32 4 156 3353
Omnet: J.NIHOUL

Management Unit of the North Sea Mathematical Models (MUMM)
Dr. George Pichot
Building AEE/BEE
Gulledelle 100
Brussels, B-1200
Phone: +32 2 773 2111
Fax: +32 2 770 6972

FRANCE

INTRODUCTION

A visit to several institutes in France resulted in very few specific details of the science and

technology work, outside of the cooperative EC projects, in the area of focus of this report. A more general review of the oceanography activity in France is reported in ref. 1, along with specific aspects of oceanographic research at the IFREMER Centre de Brest.

LABORATOIRE D'OCEANOGRAPHIE DYNAMIQUE ET CLIMATOLOGIE, UNIVERSITY OF PARIS VI

Professor Michel Crepon of the Laboratoire d'Oceanographie Dynamique et Climatologie (LODYC) at the University of Paris VI is presently involved in several EC MAST programs on deep convection in the ocean. He works with a number of researchers (mainly supported by CNRS, the French National Research Council) who are located in a university setting, and rely on contracts for research beyond salaries. He and Dr. Jean-Claude Gascard work in the EC MAST II European Subpolar Oceanography Program (ESOP) that roughly follows the Greenland Sea Project. This focuses on deep convection and production of deep water in the marginal ice zone east of Greenland.

They also work in the EC SOFARGOS program that will study convection events in the Gulf of Lions in the Mediterranean. Professor Crepon uses a 3-D model for deep convection, with several papers in press. He also has a 3-D model of the Western Mediterranean, with 10-km horizontal resolution and 20 layers in the vertical, to study relative effects of buoyancy forcing at Gibraltar, of wind stress, and surface fluxes. He currently uses daily fluxes (although not in realtime) with a 20-km fine-resolution meteorological model (called PERIDOT) that is operated by Météo France, the French weather forecasting center. This is interesting in the present context because of the controlling influence of shelf waves on the circulation and its variations in the western basin.

Professor Crepon, along with Météo France, has preliminary plans to develop and implement an operational model of the Western Mediterranean. In this case, it is part of the EC EROS 2000 Program. He, along with a former student, Dr. Courtier who now is located at ECMWF, are developing data assimilation schemes based on a variational technique using the adjoint primitive equation. He is in a research group composed of members from CNRS and Météo France that is focusing on the development of Variational Methods in Meteorology and Oceanography. They are producing a special topic course on this subject to be given in Toulon in August 1993. He also advocates neural networks for modeling nonlinear transfer functions such as occur in retrieval algorithms. Several of his papers are under review, including one in press for the *Journal of Geophysical Research* on a scatterometer application.

INSTITUT FRANÇAIS DE RECHERCHE POUR L'EXPLOITATION DE LA MER, IFREMER (FRENCH INSTITUTE OF RESEARCH INTO THE EXPLOITATION OF THE SEA)

IFREMER is the French national institute for oceanographic research and development.[1] It has laboratories all over France, although most of the physics-related research is in Brest or Toulon. The Centre de Brest has a Physical Oceanography Department and a new Remote Sensing Department, the latter headed by Dr. Kristina Katsaros, who is an air-sea interactions expert and longtime ONR contractor from the University of Washington. The Remote Sensing Department is using SSM/I data to improve monitoring of severe storms (although not in real time, because of the well-known issues of rapid access to these data). She is involved in air-sea fluxes in the French SEMAPHORE Program. She feels there are strong reasons to develop this microwave remote sensing technology to improve the accuracy of coastal weather forecasts, especially in severe conditions. Dr. Katsaros also is co-convenor of the Second International Conference on Air-Sea Interactions and Meteorology and Oceanography of the Coastal Zone to be held in Lisbon in 1994.

In the Physical Oceanography Department, Dr. Yves Desaubies is continuing his work using the French acoustic tomography system (mostly using U.S. components to date), and he convened the Second International Symposium on Global Acoustic Monitoring of the Ocean in Brest in June 1993. He is a proponent of using acoustics to monitor the ocean, especially to obtain observations on the mesoscale baroclinic structure.

The Centre de Brest is involved with CNRS and several local companies in developing a coastal

monitoring system for water quality that will use a network of buoys. It is called RAVEL (Automated Network for Monitoring the Coastal Environment, Réseau Automatisé de Veille pour l'Environnement Littoral), begun in 1991, with plans well underway to design and construct the first buoys this year. Little information was available on how the system is supposed to work, although it presumably is similar to the Seawatch system of Oceanor in Norway. Scientists at IFREMER feel that a dense network of well-instrumented buoys are necessary for making useful forecasts of water quality.

REFERENCE

1. J.P. Dugan and J. Sampson, "The Structure of Oceanographic R&D in France: Physical Oceanography and Remote Sensing at IFREMER," *ESNIB*, this issue.

Contacts

Institut Francais de Recherche pour l'Exploitation de la Mer (IFREMER), Centre de Brest
Dr. Kristina B. Katsaros
Head, Departement d'Oceanographie Spatiale
BP-70 Plouzane/Brest
France, F-29280
Phone: +33 98 22 43 16
Fax: +33 98 22 45 33
Omnet: K.KATSAROS
E-mail: katsaros@ifremer.fr

Universitie de Paris VI
Laboratoire d'Oceanographie Dynamique et de Climat (LODYC)
Dr. Michel Crepon
4 Place Jussieu, Twr #14, 2nd Floor
Paris CEDEX 05
F-75252
Phone: +33 1 44 27 49 69
Fax: +33 1 44 27 38 05
Omnet: M.CREPON

Computer Science

Connection-Machine-Based Visualization at the German Center for Mathematics and Computer Science

by Lawrence J. Rosenblum, Liaison Scientist for Computer Science at the Office of Naval Research European Office. Dr. Rosenblum is on leave from the Naval Research Laboratory, Washington, DC.

KEYWORDS: supercomputer; simulation; real-time walkthough models; volume rendering; autonoma

INTRODUCTION

Computer simulations using supercomputers have become an essential part of the scientific and engineering process. Applications span numerous problems of Navy interest. Germany has been very active in supplying its researchers with supercomputer power.

To support scientists from research centers and universities with supercomputer capabilities, a supercomputer center (HLRZ) was founded in 1986 by the large German research centers DESY Hamburg, KfA Juelich, and the German Center for Mathematics and Computer Science (GMD).

Juelich is a large (4,000 person) center for computational physics and mathematics, similar in some ways to Los Alamos National Laboratory in the U.S. GMD employs 1,400 people and conducts research and development in computer science and information technologies and in those fields of mathematics on which these technologies depend.

GMD was founded in 1968. It has an annual budget of around DM 150 million ($100M), of which DM 40 million ($13.5M) is earned from cooperative agreements. The German Federal Minister for Research and Technology supplies 90% of the remainder. GMD is headquartered in Sankt Augustin (just outside Bonn), where more than 60% of their personnel are located. Other facilities are located in Bonn and Darmstadt. In addition to these three research facilities, GMD operates research centers at the Technical University of Berlin and at the Universities of Karlsruhe and Cologne.

In 1991 GMD established a Scientific Visualization Department to work in conjunction with HLRZ. The commitment to visualization by GMD was significant; this group consists of 12 scientists plus a support staff and has been well funded, equipment-wise. They have many types of computers available, but much of their research uses the 16,000 processor Connection Machine (CM-2). They are currently purchasing a Connection Machine CM-5 and a Kendall Square parallel computer. The Visualization Department performs basic research in graphics and visualization algorithms as well as applications across several scientific domains. Major research topics include interactive data visualization and real-time walkthrough models, interactive "steering" of supercomputer computations, virtual reality using parallel machines, and the development of visualization and data handling algorithms for parallel machines.

VOLUME RENDERING

One research topic under investigation is volume rendering methods for massively parallel machines. As did Yagel and Kaufman,[1] the GMD researchers observe that a ray cast from the image plane yields a template that can be used to reduce processing requirements. To avoid view-dependent sampling difficulties, the rays are cast from a base plane parallel to a face of the volume. All rays now no longer need be processed; it is enough to process one ray, store the results, and generate subsequent rays using this stored template. The transformation back from this base plane to the image plane is a 2-D image transformation that is simpler to solve than the original 3-D problem. The rendering is performed using Krueger's previous work[2] where he showed that volume rendering modes can be understood as specializations of an underlying transport theory model of light propagation in a participating medium. These methods are being used to enhance understanding of several types of scientific data sets including CT (conductivity, temperature) data, MRI (magnetic resonance imaging) data, and protein models. Stereoscopic displays have been developed and integrated with the volume rendering.

CELLULAR AUTONOMA

Cellular autonoma (one popular example is John Conway's "Game of Life") is a topic of growing scientific importance. Using a known rule, the value of a given cell and its neighboring cells at a given time determine the value of the cell at the next time step. In the Game of Life, two states are possible for a cell:

$$v(r,t+1) = 0 \text{ or } 1$$

where $t + 1$ is the next time step and r is a rule (e.g., at the next time step the cell lives (value 1) if an even number of its 8 neighbor pixels are alive; otherwise it dies (value 0)).

The concept extends easily to multiple states. For example, define:

$$v(r,t+1) = \begin{cases} 1 \text{ if } r = 0, 3, \text{ or } 7 \\ 0 \text{ if } r = 2 \text{ or } 5 \\ -1 \text{ otherwise} \end{cases}$$

where the rule r is the sum of the neighboring voxels, including itself, at time step t. Note that this definition is applicable to any dimension as long as we define neighbor. In 2-D, a multi-state cellular autonoma can be visualized simply by defining a color to each state and producing an animation as a function of time.

Rules can be generated that simulate physical processes. This makes cellular autonoma an attractive approach to modeling certain scientific problems. Cellular autonoma is particularly suitable to fast execution on massively parallel machines. Complex physical behaviors can be visually seen and cellular autonoma is being used to simulate mathematical models that have widespread applications to computational physics. Sample applications include simulating the Navier-Stokes equations, representing equilibrium systems in statistical

mechanics and high energy physics, and portraying the motion of complex dynamical systems and large particle systems. The Naval Research Laboratory in Washington, D.C. (to which I return in 1994) has, under the direction of Dr. Susan Numrich, a Connection-Machine-based research program that is successfully using cellular autonoma to simulate underwater acoustic propagation.[3]

Most cellular autonoma simulations are two-dimensional. Research at the GMD Visualization Department has been into visualization methods for 3-D cellular autonoma.[4] In 2-D, it is enough to portray those cells that are alive at a given time. In 3-D, this technique is insufficient unless space is only sparsely filled by "living" cells. Also, smoothing multi-state fields does not generally produce good visualizations. The GMD research team has noted that effective visualization requires encoding information about the nearest neighbors as well as global information on clusters. Based on these concepts, they are experimenting with a variety of rules and emphasize interactivity in developing the best portrayals of processes. The representations portray dense groupings of "living" cells as spheres and make use of color and transparency to portray other parameters such as specific state and information about neighboring regions.

Two types of volume rendering algorithms are offered to portray 3-D cellular autonoma. The first is a ray casting method that uses tri-cubic interpolation. This produces realism but not interactivity, for the calculations (on a 16K processor CM2) take at least 10 seconds for a 512×512 image. For interactivity, a simple splatting method is used. Since all displayed objects are spheres, the splatting is straightforward and produces pictures at rates greater than 6 frames per second. Thus splatting is used for interactive analysis, and the ray-tracing technique is used for detailed examination or for the production of final products.

These algorithms have been evaluated on a variety of rules including an interesting one that produces a convergence to an oscillation between three states. The visualization techniques developed for cellular autonoma are, of course, extensible to other 3-D application models based on integer fields.

VIRTUAL REALITY

A significant portion of the Visualization Group's efforts will be directed toward virtual reality. As noted above, this group was formed in 1991, and their efforts in virtual reality are just beginning to gear up. Monika Fleishmann, whose prior work included using virtual reality to design the Hewlett-Packard building in Berlin as well as visualizations of East and West Berlin as the wall came down, has joined GMD to lead this effort. Included in the flythrough of East Berlin mentioned above is a unique view of the Hitler Bunker in the Berlin underground that was briefly opened after a period of 40 years.

GMD's current equipment is primarily from VPL. A boom-mounted display by Fake Space Laboratories has recently been purchased and is now being implemented in a fluid dynamics application. The boom supports two small CRTs on a counterweight yoke attached through six joints to a base. While head-mounted LCD displays offer the advantages of freedom of movement, the boom can provide higher image quality and resolution than current head-mounted displays. This is because real CRTs can be used, since the user does not bear the display's weight. Intended applications include medicine, fluid flow, molecular modeling, and robotics.

Specific research topics under investigation include rendering for virtual reality, collision detection, moving objects using bounding boxes, fast transformations, and motion guidance. The research team also expects to investigate the role of sound and other ergonomic issues. The collision detection will use their Connection Machine as an exploration of the role of parallelism. Future research will include cooperative efforts with the Artificial Intelligence Division of GMD, with FhG-IAO, and with the Academy of Media Arts in Cologne.

CONCLUSIONS

Germany has a tradition of supercomputing activity for scientific and engineering simulation. In the early 1980s, several leading U.S. researchers

found supercomputers in the U.S. available primarily for defense (non-university) research. They went to Germany because of the availability of supercomputers capable of running their simulations. The subsequent testimony of these scientists before the U.S. Congress contributed to the momentum for establishing what became the NSF Supercomputer Centers. These were established to make supercomputing technology available to university researchers. This in turn resulted in the realization that scientific visualization methods were required to interpret and understand the large and complex data sets generated by these supercomputer simulations.

The U.S. community has been very active since the mid-1980s in establishing the need for visualization algorithms and their application. In Europe, the German research community is now particularly active in generating tools and research activity in visualization. This group has built a high-quality visualization facility, both hardware and software, in a short period of time. The level of activity, both research and applications, is high and is already approaching that seen at the best U.S. government or quasi-government laboratories. The size and competence of the research staff is an essential ingredient in the current and anticipated achievements of this group.

REFERENCES

1. L.J. Rosenblum, "Eurographcs '92," *ESNIB* **93-04**, 262-265 (1993).
2. W. Krueger, "The Application of Transport Theory to 3D Scalar Data Fields," Proc. IEEE Visualization '90, Computer Society Press, pp. 273-280.
3. J.B. Cole, R.A. Krutar, S.K. Numrich, and D.B. Creamer, "A Cellular Automaton Methodology for Solving the Wave Equation," Proceedings of the 7th International Conference on Supercomputing, Tokyo, Japan, July 1993.
4. W. Renz, R. Westermann, and W. Krueger, "Interactive Visualization of Three-Dimensional Cellular Autonoma," VISWIZ Report 3/19-92, Scientific Visualization Dept. of HLRZ, GMD, Sankt Augustin, Germany.

Contact

Dr. Wolfgang Krueger, Director
GMD-HLRZ. VIS
P.O. Box 1316
D-5205 Sankt Augustin 1, Germany
E-mail: krueger@viswiz.gmd.de

Materials

Orientational Phenomena in Polymers: The First St. Petersburg Polymer Meeting

by Joseph H. Magill. Dr. Magill was the Liaison Scientist for Polymeric Materials for the Office of Naval Research, European Office. He joined ONR Europe from the University of Pittsburgh, Pennsylvania, where he held professorships jointly in Materials Science and Engineering and in Chemical and Petroleum Engineering.

KEYWORDS: polymers; macromolecules; polymeric mesophases; polymer chains; polyethylene

INTRODUCTION

The organization of this first conference on "Orientational Phenomena in Polymers" (6-10 July 1992, St. Petersburg, Russia) was virtually a tour de force for the scientific community in Russia. Despite adverse circumstances, the meeting did not suffer in quality. (Some of us, myself included,

bemoaned the delay in replies to fax messages—not realizing that the supply of fax paper was depleted and that there was no money to buy more!) For all the difficulties this conference was well attended, of a high standard, and covered many salient topics in polymers physics/chemistry/technology. The meeting was cosponsored by the Academy of Sciences Moscow and the Institute of Macromolecular Physics London. Conference participants came from 22 countries: a large number were from Russian states, especially from the Academies of Sciences and Universities of Moscow and St Petersburg. With more than 30 lectures and 132 posters to choose from, this summary is from topical items of significance at this developmental period in polymers in Europe. The key areas addressed at this meeting were:

- Mechanism and Theories of Macromolecules in Polymeric Systems,
- Structure Property Relationships,
- Experimental Techniques of Production-oriented Polymers with Special Mechanical, Optical, Electrical, and Other Properties,
- Defects and Fracture of Polymers, and
- Polymeric Mesophases.

The posters, like the lectures, were wide-ranging in content—from theoretical to practical topics; potential technological polymer applications were not overlooked. Proceedings of the meeting will be published in the *International Journal of Polymeric Materials*.

POLYMER ORIENTATION AND PROPERTIES

"Deformation and Fracture of Highly Loaded Polymer Chains" was presented by Prof. H.H. Kausch (Department of Materials Polymers Laboratory, Swiss Federal Institute of Technology, Lausanne, Switzerland). He pointed out that the outstanding characteristics of macromolecules (such as chain length anisotropy and mobility) were basic determinants of their mechanical properties. Starting with the pioneering work of Zhurkov (about 25 years ago) he reviewed key developments in deformation/fracture phenomena and experimental probe to monitor or obtain results.

There is an interplay between stress transfer that is a dynamic process. There is a constant interplay between external frictional processes that impose acral stresses on the polymer microstructure and internal relaxation processes. Both molecular architecture specimen morphology (including degree of orientation) and environmental factors influence the loading and fracture behavior of extended polymer chains. Generations of researchers have devoted themselves to investigating the exact role of these factors in determining deformation and fracture in polymers, as this meeting demonstrates.

Professor Ian M. Ward (Interdisciplinary Research Center, University of Leeds, U.K.) discussed "New Developments in the Production of High Modulus and High Strength Flexible Polymers" via solid state processing. Specifically, die drawing has been used to produce poly(ethylene) (PE) fibrous composites for marine ropes that are claimed to have comparatively high extension to break. This adds a high degree of ductility and damage tolerance to the composites. Hybrid composites that involve carbon or glass fibers are combined with polyethylene fibers to provide a wide range of properties, such as high toughness and strength.

Another potential application of highly oriented plastics is their reduced permeability or resistivity to gases and liquids (when films are used as barrier materials). Other developments include the fabrication of die-drawn products in the form of rod, sheet, and tube. An engineering analysis of the mechanics of the processing was presented in this investigation. In addition, Ward presented an extensive spread of mechanical property correlations relating properties with molecular weight, time, extension, cross-link-density, and polymer composition.

Professor Marikhin (Ioffe Physico-Technical Institute, Academy of Sciences St. Petersburg), claims that the ultimate orientation (approaching theoretical) should be achievable through a series of successive drawing steps. He addressed this issue in a poster entitled "High Strength and High Modulus Polyethyleneterephthalate Films," with Drs. M.L. Milagin and L.P. Myasnikova. By using a multi-stage zone drawing technique, very stiff and strong PET films are produced that have

tensile strength of 1.7 GPa and elastic moduli of 30 GPa. Other physical characterizations of the processed sample were made by (among others) X-ray scattering (SAXS and WAXS), DSC, and birefringence. The PET used in this work was pretreated in vacuum at elevated temperature to improve its molecular mass by $\times 2$ over the normally produced commercial product.

Doctor G.K. Elyashevich (Institute of Macromolecular Compounds, Russian Academy of Sciences, Moscow) presented with her co-workers an interesting poster on "Changes in Extension." Doctor Elyashevich has published theoretical and experimental papers dealing with orientational behavior and its consequences on properties processing.

Doctor B.E. Krisyvk et al. (N.N. Semenov Institute of Chemical Physics of the Academy of Sciences of Russia, Chermogolovka, Moscow region) presented "Structure of Drawn Gel-crystallized UHMWPE as Relocated by the Spin-probe Technique." In this poster, the need for understanding structure-property relationships was stressed by using electron spin resonance (ESR) to provide valuable information on molecular dynamics. Again multi-staged zone drawing was used, and the structure in the necked zone of the UHMWPE was compared for specimens claimed to have DR 1 to $\sim$ 100 with tensile strength of 6 GPa and tensile modulus approaching 140 GPa respectively. Molecular dynamics of these processed samples was studied in the 110-360 K range. ESR analysis demonstrated a slower mobile component, with an activation energy of 30-40 kJ/mole in the high-temperature range. The second component had a lower activation energy ($\sim$6 kJ/mole) and possessed a high rotational frequency over the entire temperature range. A detailed analysis of this behavior led the investigators to the conclusion that pores or voids were localized between microfibrils. This behavior was presented as further verification of the disappearance of SAXS reflections at high sample orientations. From the ESR spectra it was deduced that the fraction of pores did not significantly alter after necking the specimens, so that ultra drawing of UHMWPE results in crystallization of the intrafibrillar disordered regions (that still contain holes). Hence, these are the main cause of the measured bulk mechanical properties being much lower than theoretical estimates, based on a single polymer chain model. Of course, it must be realized that the defects in bulk and single fiber system are very different.

A novel lecture was presented by Dr. T. Nishino (now at Eindhoven University of Technology, Eindhoven, The Netherlands). In "Orientation Mechanism of Dichroic Dyes in Solution-Cast, Ultra-drawn UHMWPE," dichroic dyes were incorporated in solution-cast ultra-drawn UHMWPE that have measured Young's moduli of 120-150 GPa (theoretical values are often claimed to be in the range 240-320 GPa) and tensile strengths of 3-6 GPa (theoretical 20-30 GPa). In highly drawn polyethylene containing dichroic dyes, alignment of the dispersed dye species permits useful anisotropic optical properties to be obtained. Moreover, a mathematical procedure was presented by Nashino to derive the (apparent) transition movement of dyes from experimental measurements.

A paper by Prof. V.G. Kulichiklin (Institute Technochemical Synthesis, Russian Academy of Sciences, Moscow) addressed structural orientation. "Processes in Liquid Crystalline Polymers" also focused the orientation of dichroic dyes in polyethylenes. The percent transmission was measured as a function of wavelength in the visible region (anthraquinone and triazo dyestuffs), but the dyestuff does not reduce transparency outside of the dye absorbance region. As anticipated, dichroic ratios were found to be a strong function of draw ratio for well processed films.

Doctor V.M. Egorov, the presenter of a joint poster on "Ultradrawn Polyethylene: Parameter of Intrachain Melting Cooperativity-Structure-Strength Relations," (with Dr. V.A. Bershtein, V.A. Marikhin and L.P. Myasnikova of the Ioffe Institute and the Russian Academy of Sciences, St. Petersburg) focussed on correlations between plasticity and strength of semi-crystalline polymers. In this study, novel work on the dependence of the tensile strength and yield point of polyethylenes (MW $\sim 10^5$ to 4.5×10^6 Daltons) on their melting characteristics were established. Experiments were conducted on variously shaped specimens (fibers, films, and rods) prepared at DR values of $\times 2$ to $\times 300$ using a variety of processing techniques. [(Details are found in the Russian literature in *Vysokomolsk. Soed* **A32**, 2380 (1990)]. Characterization of specimens was made by DSC X-ray scattering and surface energy analysis.

Samples with designated DR 150-300 were found to melt at Tm ~416 K, with ΔT_{nz} 0.05 K, and essentially no structural interface can be deduced according to Thomson-Gibbs analysis for the free energy state of the edge surface of the crystallites. For undrawn samples II-IV, the I_{SAXS} meridional peak intensities drop to zero as two stages of melting take place. These are stated to be due to lowering of intermolecular order and to transitional sequencing to a statistical type of coil.

From WAXS line broadening analysis, crystallite dimensions as a function of processing conditions were deduced from X-ray line broadening, and crystallinity determinations were also made. Crystallinity was estimated to $\leq$90 percent, while crystallite size ranged from 200-800Å in the chain direction. Discrepancies were noted between X-ray and DSC estimates of crystallinity since the thermal method is believed to be independent of point and other defects in the samples. From the simplified (classical) analysis used in this work, discrepancies were found between actual average chain length and the estimated values that are not easily accounted for.

Egorov et al. introduced the idea of mechanical "vitrification" (explained as a decrease in sample compliance) as a reason for the cessation of drawing and accountable for the "solid-state" fracture mechanism. Quantitative estimates are given for the formation of submicron cracks at the boundaries of kink bands. Interestingly, from NMR measurement it was deduced that sequential mobility in the "amorphous regions" is almost completely suppressed because of the increase in the orientational stress near the maximum deformation ratio (even though the drawing temperature is close to the melting point). The magnitude or extent of deformation is determined by polymer type, initial morphological structure, and conditions of drawing (temperature, rate, and molecular weight, as well as molar mass distribution). These workers also tried to correlate microstructure (composed of microfibrils and macro- and microcracks). Apart from its scientific merits, this work on polymer orientation is an example of research cooperativity that sometimes exists between different scientific institutes, provided that someone of the stature of Prof. Marikhin is available to coordinate it.

In an investigation of "The Stepwise Deformation of Oriented Polyethylene," Drs. N.N. Peschanskaya and L.P. Myasnikova (A.F. Ioffe Physico-Technical Institute, St. Petersburg) showed that multiple step drawing was a recommended way to change morphology and to improve mechanical properties. The use of an interferometric record of polymer creep enabled these workers to observe deformation steps (groups) on the micron-submicron scale for polyethylenes drawn in the $\times$7 to $\times$200 at 100°C and tested and monitored continuously in creep tension. Claims were made that deformation steps could be correlated with intra- and interfibrillar regions of the deforming polymer. The underlying supramolecular structure was also probed by scanning and transmission electron microscopy and correlated with deformation practices. For effective property improvement from a fractural and commercial application view, there must be a practical limit in the economics of repetitive or "cascading drawability" for the processing of large polymer workpieces. For fibrous and other small samples, the procedure is manageable.

Doctors L.B. Stroganov, E.B. Barnatov, V.P. Shebaev, and N.A. Plate (Chemistry Department, Moscow State University, Moscow, Russia) presented a poster on "Dynamics of Director Reorientation in Liquid Crystal Polymers." They proposed a new technique for determining the characteristic relaxation time τ and rotational viscosity η for liquid crystalline polymers (LCPs) oriented in a magnetic field. Two series of NMR spectra were compared. They are obtained at various times and, correspondingly, at various angles between the director orientation and the magnetic field. The technique offers a procedure for monitoring changes occurring in oriented structure during the director reorientation. It also permits an analysis of the variation in the spatial distribution of the director.

The results that are obtained from LCP of nematic polyacrylates and main chain polyesters are:

- for comb-shaped polyesters reorientation, the director reorientation is distributed, but for polyacrylates it is retained;
- within a wide range of temperature and molar mass, the reorientation in the comb-shaped polyacrylates may be accounted for with a monodomain model; and
- the temperature dependence of η is found to be Arrhenius, whereas the molar mass of

polyacrylates and their viscosity is given by the relationship $\eta \sim MW^{\gamma}$ where $0.9 < \gamma < 1.98$.

Consideration was also given to the fracture of polymers, which is a very important applications aspect. A study dealing with "Fracture Kinetics for Polymers in a Wide Temperature Range" was presented by Dr. V.I. Vettegren and coworkers (A.F. Ioffe Physico-Technical Institute and "The Institute of Macromolecular Compounds," St. Petersburg). Several polymers (polyolefins, polyamides, polyimides, etc.) were investigated from 20 K to their respective melting points. Plots were limited to the temperature range of feasibility—negative deviations appearing at low temperatures and positive deviations appearing at high temperatures. Some theoretical explanation of this behavior was presented, substituting Bose for Boltzmann statistics, but the analysis still appears to have limited value.

Orientation behaviors in some complicated polypolefims were also reported. The "Mechanical Behavior of Polyethylene Naphthalate Fibres (PEN) Near the Glass-Rubber Transition Temperature" was reported by Profs. R.A. Huijts and A.J. de Vries (AKZO Research Laboratories Arnhem, The Netherlands). This polymer has interesting commercial applications as a fiber. It is superior to PET, since the large ring introduces backbone chain stiffness. Mechanical tests made on PEN in the range of 90-160°C were made, and necking to rubber-like behavior by stress-strain was noted between 120 and 130°C, i.e., 40° above PET. However, the yield stress of PEN is below that of PET fiber. Dynamical mechanical measurements made between 0 and 200°C pointed up a single pronounced peak where the loss τ exhibited above that of PET, showing that the thermal mechanical stability of PEN is superior. Other aspects of this polymer including its cost relative to PET were not discussed.

The "Effect of Chain Rigidity Upon Polymer Orientational Strengthening" was studied by Dr. M.V. Shablygin and coworkers at the Institute of Synthetic Fibers, Tver, Russia. They documented that orientation was the primary method to reduce strengthening for many polymers. Orientation carried out above the respective T_g of each polymer was measured by polarized infrared spectroscopy. In general, chain stiffening induced by chemical substituents proved to be an effective procedure for property enhancement.

Still on the subject of orientation, M. Pietralla and coworkers (Experimental Physics Department, University of Ulm, Federal Republic of Germany) presented a poster entitled "Thermal Conductivity in Ultra-Oriented Polyethylene." Draw ratios between $\times 12$ and $\times 250$ were reported and measured, showing a levelling-off of the diffusivity about $\times 50$. The maximum diffusivity was $\sim 1.9 \times 10^{-5} m^2/S$ which corresponded to a maximum thermal conductivity of 35.5 w/mk (a value $\times 4$ that of steel itself!). From an extrapolation of the conductivity versus modulus, an ultimate modulus of 300 GPa was obtained (in line with some theoretical predictions); an upper limit of conductivity ~ 880 w/mk was estimated. These well-conducted studies appear to provide a valid way to monitor structural imperfection when consideration was given to the change in values of k^{I} (storage) and K^{II} (loss) conductivity with DR and modulus changes expressed as a function of modulus. Elsewhere, in the literature there have been measurements of k with direction in rolltruded plastics that have a 3D morphology that were discussed by the writer at this conference.

Doctor J.H. Magill (former Liaison Scientist for Polymer Materials at ONR Europe) made a presentation on "Rolltrusion Processing of Polymers for Property Enhancement." He pointed out that rolltrusion is a single-step solid-state deformation process that has been successfully applied to many polymers and copolymers to produce unique properties. Property enhancement results in 3D mechanically improved behavior over the original workpiece without the need for cross-plying. Processing-structure-property relationships have been established. Rolltruded polymers are transparent since they are free of spherulites; rather, they are composed of anisotropic small crystallites formed from spherulites. The crystallites are crystallographically arrayed and inter-connected by tie molecules that provide property improvement in three mutually perpendicular directions.

Thin films have also been made, and these may be used as membranes for the separation of small molecules. Permselective membranes so

formed are pin-hole free and very strong, with a regulated 3D morphology. The rolltrusion technique is not restricted by the solubility constraints inherent in preparing solvent-based thin films. Consequently, engineering plastics can be made into membranes without regard for their limited solvent solubility. Rolltrusion has now been established as a universal procedure for property enhancement of commercial and engineering polymers.

THERMOTROPIC POLYMERS

Professor Y.K. Godovsky (Karpov Institute of Physical Chemistry, Department of Materials, Moscow, Russia) gave an interesting presentation on "Orientational Phenomena in Flexible Mesophase Polymers." Specifically, he discussed the physical properties of linear poly(siloxanes) and poly(phosphazenes), which he regarded as disordered mesophases with a high level of molecular mobility. This process gives rise to orientational phenomena as well as self-reinforcement because of the mesophase formation; this can persist to relatively high temperatures, depending on the macromolecule. This self reinforcing that occurs may be regarded as a novel type of composite material. It can be brought about through blending high-performance polymers such as poly(butylenephthalate), PBT, poly(ethyleneterephthalate), PET, or poly-(carbolate) PC with an appropriate thermotropic crystalline polyester, LCP. After molding the LCP component (usually fibrous in nature) it is found to be well-aligned along the flow direction, and this is responsible for the self-reinforcing effect. Components are usually melt blended and formed by using a capillary rheometer to yield textures that are well characterized by conventional techniques such as X-ray (WAXS and SAXS) NMR, DSC and optical microscopy. Mechanical properties of the "oriented composites" are improved over the original matrix, the degree to which this occurs depends on the processing conditions in the rheometer.

Professor Samuel I. Stupp (University of Illinois) presented a paper on "Organizing Assemblies of Liquid Crystalline (LC) Polymers in External Fields." He noted that field orientation in LC assemblies has received much attention in recent years, and there are many salient features of orientation in main chain, nonlinear optical (NLO), and two-dimensional (2D) polymers. A magnetic field induces considerable time-dependent orientation in the field direction that is also slowed down by polymer molar mass. Aging of mesophases is also a strong time-dependent process expressed as function of the order parameter of the system. Domains are observed to grow or coarsen with time as single crystals in Ostwald ripening.

Polyphosphazenes are being strongly investigated at the Institute of Organo-element Compounds of the Russian Academy of Sciences. Dr. Dzidra R. Tur et al. (in cooperation with Prof. Vladimir S. Papkov) has synthesized relatively pure high molecular weight polymers that have a small concentration of chemical defects in the macromolecule. Some interesting phase behavior has been reported. When the length of the alkoxy side group is varied in poly(dialkoxy-phosphazenes), only linear side chains with more than six carbon atoms appear to have the ability to crystallize, despite the backbone flexibility of the polymers. For shorter chain length, the driving force for molecular ordering even in the mesostate appears to be low. They state that sufficient defects along with intra- and intermolecular coordination discourages mesophase formation and prevent crystallization. Diffractograms (X-ray and thermal) are in accordance with optical microscopy of polyphosphazene films. Surprisingly, none of the specimens were oriented and stored for a long time in a temperature regime that would favor ordering. Kinetics is critical in the formation of many mesophases, polyphosphazene with polar groups being no exception. The non-polar side chains seem to exhibit unique and inexplicable behavior. In further (current) studies on poly(dialkoxyphosphazenes), Prof. V.S. Papkov et al. have concluded that the self-organization of these macromolecules is controlled by side chain interactions and that the flexible backbone allows all of these to be realized. He states that polar P-O-C bridges (impurities of low degree) may produce some kind of stabilizing influence on the mesogenic state, although the rationalization seems to be vague to the writer.

Doctor G. Lieser lectured on "Orientational Phenomena in the Solid State of Woven-like Chains." This paper was co-authored with Prof. Gehard Wegner also from the Max Planck Institut

für Polymerforschung, D6500 Mainz, FRG. He pointed out that worm-like molecules like poly(5,7-dodecadyne-1, 12-diol bis(4-butoxycarbonyl methyl)urethane) (i.e., P-4-BCMU, a soluble diacetylene) and soluble phthalocyaninatopolysiloxane with alkyl-side chains (PcPS) are able to form lyotropic phases. This ability is often exploited in fiber-forming polymers where chain alignment is facilitated by making use of the inherently ordered aligned nematic phase. In the absence of external perturbations, chain ends (that give rise to defects) are distributed randomly throughout the samples and concentrated between lamellae having thicknesses proportional to the chain length. Correlations were made between lamellae widths by TEM, SAXS, long period, and chain length. The polarization microscope was used to study a schlieren texture and to determine that disclination density decreases with time and tends toward equilibrium after two weeks. From the characterization methods it was determined that the number average molecular weight of the polymers corresponded nicely to the thickness of the lamellae. Segregation of polymer molecules create discrete morphologies that are dependent on sample history and are significant in determining LC properties.

Doctor T. Vahlenkamp of Professor Gehard Wegner's group presented a poster on "Main Chain Orientation in Monolayers of Hairy Rapid Polymers: Experiment and Theory." The polymers in question were tetra(methoxy)-tetra(octoxy)-phthalocyaninato-polysiloxane), poly-(γ-methyl-L-glutamate)-co-γ-n-octadenyl-L-glutamate, and several other cellulose ethers. A Langmuir-Blodgett (LB) technique was used to orient these lyotropic materials through the "dipping" method.

The influence of orientation on polymeric mesophases received considerable attention. An interesting presentation was made by Dr. I.A. Gorshkova with several coworkers from the A.F. Ioffe Physico-Technical Institute, St. Petersburg. In "Effects of Orientation on the Properties of Liquid Crystalline Polymers" they compared the changes in physical properties of poly(-p-phenyleneterepthalate) (PPT) with two other undocumented polyesters for comparisons with temperature; this revealed that PPT was superior. There were several pertinent remarks on the jet drawing of these and other LCPs. However, there was no discussion of the relaxation behavior of these systems with processing conditions. The relative merits of heat treatment below and above the mesophase transition were addressed, but no firm conclusions were reached except that recrystallization or macromolecular network formation occurs with heat treatment.

In a poster concerned with orientational processes in poly(fluor-organophosphazenes) and poly(diethylsiloxanes), M.V. Gerasimov et.al., pointed out that during drawing a significant effect of stress on the $T_{(1)}$ transition (crystalline→mesophase transition) was found from X-ray investigations. This was not detailed in explanation. Dr. A.N. Zadorin et al. (Topchiev Institute of Petrochemical Synthesis, Leninsky pr. Moscow) stressed that two crystalline forms of poly(trifluoro-ethoxyphosphazene) were formed from the cooled thermotropic state. This material was of very high molecular weight, $>10^7$ Daltons, and low polydispersity, in contrast with other polymers of this kind reported in the literature.

POLYMER RELAXATION

For the random copolymers when a similar stretching condition was used, strain rate E and (T-T_g) the orientation depends on the copolymer composition. Here also identical behavior results when the frictional coefficients are identical. For compatible blends, each component of the blend has a different orientation, but the thermodynamic interaction between species is responsible for the coupling effect between species.

Professor Leonard Monnerie (Ecolé Supérieure de Physique et de Chimie Industrelles de Paris, Paris, France) lectured on "Orientation and Chain Relaxation of Amorphous Polymers." Basically the presentation dealt with orientation of well-characterized polymers above their respective glass transition temperatures. It is necessary to understand the molecular mechanism associated with the processing conditions to define the processing per se. Many optical and spectroscopic techniques (Fourier Transform infrared dichroism being one of the most useful for quantifying orientation). A quantitative comparison of results with the Doi-Edward (D-E) reputation model indicates that orientational coupling between chain segments and their oriented surrounding. Deuteration of one

species was carried out to characterize independently the orientation functions of each species.

In a poster study by Monnerie et al. that involved several collaborators from other institutions, the molecular mechanisms in the deformation of PET films were studied by using spectroscopic techniques. This fundamental study was undertaken to gain closer insight and understanding of the industrial stretching processes of polymers. In the laboratory in the isothermal range 85-110°C at constant loads of 1.2 to 5.5. MPa, respectively, flow-induced crystallization occurs. The transformation is fast (seconds). The stretched products were also extensively investigated; it has been shown that the amorphous phase is more weakly oriented at the higher temperatures (>100°). Before crystallization takes place, the D-E model applies; afterwards, crystallization inhibits large-scale motion of the chains. No relaxation is possible except for distances smaller than the average dimensions between crystallites. At low and high temperatures respectively significant difference in the rate and mechanism of deformation were established as quantitatively different and give rise to differences in products produced. At higher temperatures, there are a layer number of monomers between entanglements and therefore reduction in network strength is reduced.

RANDOM COPOLYMERS/BLENDS

Doctor Evgeniy M. Antipov and his group at the Institute of Petrochemical Synthesis, the Russian Academy of Sciences, Moscow, presented several posters dealing with various polymeric mesophases that included polyphosphazenes and polyesters. Interestingly, the thermotropic polyester work performed in collaboration with Dr. Manfred Stamm and Prof. Erhard W. Fischer (Max Planck Institute). Under the heading "Temperature Evolution of the Structure of the Thermotropic Copolyester:-Poly(phenyl-p-phenylene)-co-(terephthalate)-co-(p-hydroxybenzoate), they noted that the random thermotropic copolymer composed of terephthalic acid, phenylhydroquinone, and p-hydrobenzoic acid in molar ratio 45/45/10 showed (by X-ray analysis) two well-ordered, 3D orthorhombic unit cells of different sizes. This was despite the random substitution of monomer groups (of equal length).

Doctor. S.A. Kuptsov and coworkers (Institute of Chemical Physics and Institute of Petrochemical Synthesis, Russian Academy of Sciences, V.I. Lenin, Moscow, Pedagogical State University, Moscow) presented a poster on "The Orientational Effects in Polyolefins and their Blends under Plastic Flow." They established that:

- for monoclinic HDPE, the crystallite orientation is not dependent on shear angle;
- for orthorhombic HDPE, the C axis is along the flow direction;
- for PP there is loss of 3D orientation within the crystallites but chain orientation persists along the tangential direction;
- for blends PP/HDPE, the PP components appear hardly oriented except when PP is the matrix component. In this case, tangential orientation of the C axis is observed; and
- with EPDM content in excess of 50 percent, PP becomes the dispersed phase and orientation effects are absent.

Material properties were not documented for these processed plastics.

THEORY

An interesting theoretical investigation on "Molecular Models of Structural Defects in Polymer Crystals" was presented by Dr. Valery V. Ginsberg and others from the N.N. Semenov Institute of Chemical Physics, Moscow. Pointing out the many structural defects inherent in polymer crystals, they emphasized the unique features because of the high anisotropy and structural hierarchy of polymer crystals.

On the basis of model potentials of inter- and intramolecular interactions obtained by computer simulation and symmetry conditions for orthorhombic polyethylene an analysis was presented. Approximate solutions describing vacancies in crystals of polyethylene were obtained where all displacements and rotations were highly localized in a single chain. The role of localized defects in structural transitions was also studied. It was stated that the shape and energy of a single edge dislocation may be calculated; so too can the Peierls barrier. It is noteworthy that screw dislocations with their Burger's vector parallel to the

chain axis can move relatively freely. This explains why the process of plasticity is only limited by dislocation attractions. From the dislocation dipoles the stress needed for dipolar-dipolar dissociation was calculated.

SUMMARY

This meeting produced many more posters and presentations. Some of the experimental work presented by the former Eastern European communities lacked the spark of novelty and originality at the time of presentation, presumably because of the adverse circumstances and limited funds now available in Russia for the repair and purchase of equipment. On the theoretical side the story was different.

At the end of the conference (in addition to the usual question time following lectures) a two-hour discussion period provided a more in-depth evaluation of the conference and the status of our understanding of orientation in polymers from theoretical and experimental points of view. There was lively and critical discussion, as well as some agreement, concerning progress made in recent years on the interplay and diversity among and between different types of homopolymers and blends, including polymeric mesophases and copolymers. One of the key goals in polymer orientation has been the thrust for higher modulus and higher strength materials. A main objective for some investigators has been the attainment of properties approaching the theoretical limits. These are now fairly well understood for polymers evaluated in tension, but are less well known in compression. Even so, we are still ignorant of some fundamentals that (in the writer's opinion) enables one to calculate, for instance, fracture strength from the tensile strength and vice versa, in a meaningful manner!

There was also some discussion about the inadequacy of the crystallite orientation factor, f_c, to account for and to correlate with mechanical properties such as tensile strength (for example). Instead, f_a (the amorphous orientation factor) correlates more directly with engineering properties than f_c from low to very high deformation ratios. Successful theoretical modeling of the f_c, especially at relatively low deformation ratios (≤ 5) has been carried out. However, these procedures fail to involve the high draw ratio conditions (upwards of $\times 100$) on a molecular and morphological bases, particularly when using a two-phase Hermann model. (We know this is not truly representative of a highly anisotropic polymer system). The crystalline orientation "saturates" well below a DR $\times 10$. A more complex model of the anisotropic state is needed if we are to include all orientations in a meaningful manner. Will this goal ever come about?

European Mechanics Research Community Organizes Itself

by D.G. Crighton, Head of the Department of Applied Mathematics and Theoretical Physics, University of Cambridge, U.K., and Chairman of the European Mechanics Council (EUROMECH)

KEYWORDS: EUROMECH; conferences; colloquia; scientific interaction; organization

EUROPEAN MECHANICS COUNCIL

The European Mechanics Council was set up in 1964 as the European Mechanics Committee, to organize mechanics activities in Europe. These activities have become widely known as EUROMECH Colloquia and Conferences.

EUROMECH Colloquium 1 (Boundary Layers and Jets Along Highly Curved Walls — Coanda Effect; R. Wille, chairman) was held in Berlin in April 1965. EUROMECH Colloquium 300 (Interaction Between Vorticity Fields and Boundaries; C.R. Kaykayoglu, chairman) was held in Istanbul in September 1993. These colloquia are

specialized meetings for between 30 and 70 participants at the invitation of a chairman who is appointed by the Council. They have ranged very widely over fluid and solid mechanics (dealing with theoretical, experimental, and computational approaches to both fundamental and applied mechanics). Their locations have ranged over the geographical area of Europe—from Helsinki, Luleå, and St. Petersburg in the north to Reggio Calabria, Palermo, and Rhodos in the south; from Lisbon and Bordeaux in the west to Nizhny Novgorod and Perm in the east (actually on a ship sailing from Perm to Moscow). Participation in EUROMECH Colloquia by scientists from Eastern Europe has always been a strong feature; 30 colloquia have been held in Poland alone; colloquia are now being regularly held in countries of the former Soviet Union. They have proven to be scientifically effective and provide excellent opportunities for the establishment of interactions between scientists in Europe.

The European Mechanics Council now also runs regular series of conferences on a much larger scale. European Turbulence Conferences have been held every two years since 1986, each attracting about 200 participants; a series of European Nonlinear Oscillations Conferences, with about the same number of participants, are beginning in 1993. Possibilities for other series of such conferences in broad central themes in mechanics are also under discussion (for example, conferences concentrating on two-phase flow and on composite materials). In addition, the council has organized larger conferences (attracting about 400 participants): the European Fluid Mechanics Conference and the European Solid Mechanics Conference. It now proposes to make these the first of two series of Conferences at three-year intervals. The first of these were held in September 1991, in Cambridge and in Munich respectively; the second of each series will take place in September 1994, in Warsaw and in Genoa, respectively.

Proposals for EUROMECH Colloquia (for colloquia to be held the following calendar year) are received each year by the council at its April meeting. There is considerable competition to organize these Colloquia, and the Council has to make a selection (among 17 for 1993, for example) from a larger number of proposals submitted. Once approved, the subsequent organization of a EUROMECH Colloquium is entrusted entirely to a chairman (possibly with a co-chairman) appointed by the council. The organization of each of the series of conferences is in the hands of a Standing Committee whose members are drawn from all countries of Europe. The Standing Committee is in charge of the overall scientific planning and program of a conference, and is assisted by a Local Organizing Committee that makes the detailed arrangements.

EUROMECH CORRESPONDENTS

To make the best selection of participants, chairmen of EUROMECH Colloquia need information on the interests and activities of scientists in all European countries. For conferences, which are open to all interested scientists, there is a need to make information about them available. To help chairpersons and the council in these tasks, a network of EUROMECH Correspondents has been established. It has correspondents qualified in fluid and in solid mechanics in virtually every country in Europe—more than 70 correspondents in all. A particular duty of these correspondents is to identify, in their own or other countries, talented young scientists who may not yet be known to a chairperson, but who should be encouraged and helped to attend colloquia and conferences. Correspondents also make recommendations to the council for action and have been very involved in recent discussions of proposals to transform the Council into a society.

EUROMECH—EUROPEAN MECHANICS SOCIETY

Mechanics is a long-established branch of science. It has a long and rich history—in the course of which many important developments have occurred in Europe. Mechanics is also a distinctive branch of science—distinguished from physics, from mathematics, and from engineering. It is an outward-looking subject, still in a phase of very strong research development, and with applications and interactions with many other branches of physical, biological, and engineering science. Mechanics is important to all countries in Europe, not the least of which is that it is a relatively inexpensive subject in which all countries can participate at a good scientific level at modest expense.

It also holds great technological importance for the industries of all countries. Other areas of science for which comparable claims may be made now have a voice to speak for them at a European level, in the form of bodies such as the European Physical Society, the European Mathematical Society, and the European Geophysical Society. The subject of mechanics is not yet represented by such a society (and it can be argued, that if it is not, it will be spoken for by organizations representing physics, or mathematics, or geophysics, or some branch of engineering science). One consequence of this might be a loss of funding to mechanics, especially in the context of new European funding mechanisms for scientific research and collaboration. A more serious long-term consequence could be systematic decline in the perceived importance of mechanics in university education and scientific research programs generally.

The European Mechanics Council has been giving much thought to these and related issues, and has written first to all EUROMECH Correspondents, and then more recently to all national organizations in mechanics in Europe, seeking their views first on the question of whether a society is needed for mechanics in Europe, and second as to whether EUROMECH itself is best placed to create such a society through transformation of itself. Replies from correspondents have been overwhelmingly in favor both of the establishment of a society, and of the transformation of the council into the governing body of that society. This response was considered by the council at a meeting in Berlin in February 1992. After extensive discussion, the council resolved unanimously to begin the process of transformation into a society, with the appropriate structure in place by the beginning of 1995. A working group has met to draft statutes and other constitutional documents. The proposed organizational arrangements for the society should be available by mid 1993.

The first activities of the society will involve the extension of the program of colloquia and conferences, to broaden their coverage and scope, to arrange for the organization of such meetings throughout Europe, and to have the fullest participation in them from all qualified scientists. EUROMECH Newsletters will be regularly distributed by the society to its members to systematically publicize activities. These activities are expected to involve, for example, funding of research programs and conferences in mechanics and educational issues relating to the position of mechanics in the university curriculum. In all these activities, the society will strive to complement existing national and international activities.

EUROMECH MEETINGS, 1993 AND 1994

The European Mechanics Council has overall responsibility for EUROMECH Colloquia and EUROMECH Conferences. The latter presently comprise the European Fluid Mechanics Conference, the European Solid Mechanics Conference, the European Turbulence Conference, and the European Nonlinear Oscillations Conference. General information about colloquia and conferences can be obtained from the secretary of the European Mechanics Council:

Professor B. Lundberg
Department of Technology
School of Engineering
Uppsala University
Box 534, S-751 21 Uppsala
Sweden.

EUROMECH Colloquia

EUROMECH Colloquia are informal meetings on specialized topics. Participation is restricted to a small number of European researchers who are actively engaged in the field of each colloquium. The organization of each colloquium, including the selection of participants for invitation, is entrusted to a chairman. Proceedings are not normally published. Those who are interested in taking part in a colloquium should write to the appropriate Chairman. EUROMECH number, title, chairman, dates, and location for upcoming EUROMECH Colloquia are given below. Information about EUROMECH Colloquia in 1994 will be available soon.

309. *Optical Flow Diagnostics*

Dr K.A. Bütefisch
DLR Institute for Experimental Fluid Mechanics
Bunsenstraße 10

D-3400 Göttingen, Germany
Dr. J.R. Bonnet, Poitiers, and Dr W.H. Beck, Göttingen
28 September - 1 October 1993, Götingen, Germany

310. *Sediment Transport Mechanisms in Coastal Environments and Rivers*

Prof. M.M. Belorgey
Laboratoire de Mécanique des Fluides
Universvité du Havre
Quai Frissard BP 265
F-76055 Le Havre Cédex, France
Dr. J.F.A. Sleath, Cambridge,
13-17 September 1993, Le Havre, France

311. *Blood-Wall Interaction*

Prof. K. Affeld
Universitätsklinikum Rudolf Virchow
Spandauer Damm 130
D-1000 Berlin 19, Germany
18-21 October 1993, Berlin, Germany

312. *Turbulence and Vortices in Hypersonic Flows*

Dr F.R. Grosche
DLR Institute for Experimental Fluid Mechanics
Bunsenstraße 10
D-3400 Göttingen, Germany
5-7 October 1993, Göttingen, Germany

313. *CFD in Turbomachinery and Experimental Validation*

Prof. J.L. Kueny
CREMHyG, BP 95
F-38402 Saint Martin d'Hères, France
Prof. F. Leboeuf, Ecully
9-10 December 1993, Val d'Isére (Rhones Alps), France

314. *Effectiveness of Shell-Theory Formulations for Numerical Solutions*

Prof. E.L. Axelrad
Universität der Bundeswehr München
W. -Heisenberg-Weg 39
D-8014 Newbiberg, Germany
Prof. F.A. Emmerling, Neubiberg
14-18 September 1993, Munich-Neubiberg, Germany

EUROMECH Conferences

EUROMECH Conferences are broad in scientific scope. They are open to all interested participants and are expected to have between 150 and 600 participants. The general purpose is to provide opportunities for scientists and engineers from all parts of Europe to meet and discuss current research. The responsibility for each series of Conferences is delegated to a Standing Committee. Detailed organizational work is carried out by Local Organizing Committees (LOCs). Contact the chairman of the appropriate LOC for further information about participating in a future conference:

5th European Turbulence Conference
Summer 1994 (details available from the Secretary)

2nd European Solid Mechanics Conference
Prof. A. del Grosso
Istituto di Scienza delle Costruzioni
Università di Genova
Via Montallegro 1
I-16145 Genova, Italy
12-16 September 1994, Genoa, Italy

2nd European Fluid Mechanics Conference
Prof. H. Zorski
Institute of Fundamental Technological Research
Polish Academy of Sciences
Swietokrzyska 21
00-049 Warsaw, Poland
20-24 September 1994, Warsaw, Poland

Contact

Prof. D.G. Crighton
Dept. of Applied Mathematics and Theoretical Physics
University of Cambridge
Silver Street
Cambridge CB3 9EW
United Kingdom
Phone: +44 0223 337860
Fax: +44 0223 337918

Oceanography

The Structure of Oceanographic R&D in France: Physical Oceanography and Remote Sensing at IFREMER

by John P. Dugan and CDR John A. Sampson, USN. Dr. Dugan was the Liaison Scientist for Physical Oceanography at the Office of Naval Research European Office. Previously he formed and directed the Field Measurements Department for Areté Associates. Earlier, he was at the Naval Research Laboratory, Washington, D.C. CDR Sampson was the Undersea Systems Liaison Officer for the Office of Naval Research European Office.

KEYWORDS: IFREMER; CNRS; oceanography; coastal environment; biotechnology

INTRODUCTION

This article provides a brief introduction to the general structure of oceanographic research and development (R&D) in France, and a more detailed look at the primary oceanographic research institute, the Institut Francais de Recherche pour l'Exploitation de la Mer (IFREMER). Research in the public sector in France is concentrated in a number of large organizations. The Centre National de la Recherche Scientifique (CNRS) is the primary research organization; it crosses many disciplinary boundaries. Other organizations work within rather narrowly defined sectors. The French R&D system, both within and outside of CNRS, is based on a rigid structure of organizations. Little opportunity exists to change budgets or staffing levels quickly, to reorient the direction of research, or to transfer staff between organizations or laboratories. CNRS is a collection of small laboratories that are frequently based in the universities, but it also contains a number of large facilities. Areas of responsibility outside of CNRS typically are more applied, and laboratories in these areas often work closely with industry in their sectors.

The CNRS is the largest of the public research organizations. It has a budget of almost FF 10 billion (FF 5.35 ≈ U.S. $1) and employs about 26,000 people in 300 of its own and 1000 associated laboratories. Many oceanographers associated with universities actually are CNRS employees. Recent policies (including joint CNRS-industry laboratories and exploitation companies) favor the improvement of technology transfer to industry. One example is the Laboratoire d'Automatique et d'Analyse des Systemes (LAAS), which has close links with industry, especially in the field of robotics. LAAS was founded in 1967, with origins in the aerospace sector in Toulouse. It is large in comparison with most CNRS laboratories and has a staff of approximately 380 (as of 1985, 267 researchers and researcher-teachers, 82 engineering technicians and administrative personnel, and 32 postgraduate students).

The Centre National d'Etudes Spatiales (CNES) is an Industry Ministry establishment with responsibility for the civilian space program. Although it is a major employer (a total staff of about 2200), its directly controlled material resources are limited, mostly residing in its subsidiary, Arianespace, or shared with other national laboratories. It is principally a design and project management organization, and subcontracts a high fraction of its work to industry. Funding of about FF 5.5 billion comes from the civil R&D budget. It often is mentioned with the European Space Agency (ESA) with respect to remote sensing of the ocean, but most of the actual research is carried out by either CNRS or IFREMER personnel.

Finally, IFREMER is the primary oceanographic R&D agency, and its structure and goals are discussed in detail in the following sections.

INSTITUT FRANÇAIS DE RECHERCHE POUR L'EXPLOITATION DE LA MER (IFREMER)

The French Research Institute for the Exploitation of the Sea (IFREMER) is a public corporation under the joint authority of the Ministry for Research and the Ministry for the Sea. It was created in 1984 by the merger of the National Center for the Exploitation of the Oceans (CNEXO) and the Scientific and Technical Institute of Marine Fisheries (ISTPM). Its five broad missions are to:

- conduct marine scientific and technological research,
- stimulate national policy and research programs,
- manage the oceanographic fleet and facilities,
- monitor sea resources and the coastal environment, and
- transfer technology to French industry.

IFREMER's headquarters are near Paris; its five major research centers are in Boulonge-sur-Mer on the English Channel, Brest and Nantes on the Atlantic, Toulon on the Mediterranean, and Tahiti in the Pacific. Fifteen smaller stations are maintained along the French coast as well as three stations in the Western Atlantic, one in the Indian Ocean, and one in the Southwestern Pacific. The organization has 10 ships, including 4 ocean-going general oceanographic vessels, 1 ocean-going support vessel, 2 cold-region and high-seas fishing vessels, 2 coastal fishing vessels, and a coastal oceanographic vessel. They also have two manned submersibles: *Nautile* (6,000 m) and *Cyana* (3,000 m), plus 5 unmanned submersibles and robots.

Budget

IFREMER's 1992 budget was FF 940 million (≈ U.S. $190 million). Of this total, 87% came directly from the French government; the remainder was generated by sales of their services, products, investments by other organizations, etc. Table 1 shows how this money was spent.

Table 1. 1992 Funding

	French francs (millions)	U.S. $ (approx.) (millions)
Direct operating expenses	385.4	77
Personnel	149.4	30
Fleet operations	150.5	30
Centers and laboratories	16.5	3
Offshore drilling project		
Strategic plan investments	26.4	5
Ocean research	21.2	4
Coastal environment	53.0	11
Living resources	31.7	6
Engineering and technology	63.2	13
Fleet renewal	42.7	9
Other		

Personnel

IFREMER directly employs approximately 1200 people. An additional 600 work for various subsidiaries. The distribution of personnel is:

Geographic distribution

Headquarters and overseas delegations	145 (12%)
Brest (and associated stations)	537 (45%)
Nantes (and asscociated stations)	268 (23%)
Toulon (and associated stations)	116 (10%)
Boulogne (and associated stations)	055 (5%)
Tahiti	69 (6%)

Functional distribution

Office of President/ Director General	107 (9%)
Accounting, Logistics, Administration	219 (18%)
Environment and Coastal Management Directorate	217 (18%)
Engineering, Technology, and Data Processing Directorate	204 (17%)
Naval Operations and Resources Directorate	9 (1%)
Oceanic Research Directorate	115 (10%)
Living Resources Directorate	319 (27%)

IFREMER considers 49.5% of its employees to be "managers" and 50.5% to be "execution personnel."

Strategic Plan

A five-year Strategic Plan (1991-1995) establishes six major objectives for the Institute (slightly different from the overall goals stated above):

- develop internationally recognized centers of expertise;
- increase scientific and industrial openness;
- play a leading role in establishing European oceanographic policy;
- increase recognition of IFREMER among political, economic, and scientific decision makers;
- improve efficiency; and
- consolidate financial resources.

The Strategic Plan also establishes five major research themes:

- Ocean Research: climatic forecasting and global ocean observation;
- Evolution of the coastal environment;
- Living Resources: value enhancement of fisheries and aquaculture, particularly through biotechnology;
- Engineering and Technology: instrumentation and underwater intervention; and
- Fleet renewal.

Oceanic Research Directorate

Marine Geosciences Department
- Lithosphere Laboratory
- Accretion-Hydrothermalism Laboratory
- Sedimentary Environment Laboratory

Deep-Sea Environment and Associated Biotechnologies Department
- Deep-Sea Environment "Department"
- Biotechnology Laboratory

Physical and Space Oceanography Department
- Laboratory of Ocean Physics (LPO)
- Space Oceanography "Department"

IFREMER is the principal French participant in several major international oceanographic research programs, including the World Ocean Circulation Experiment (WOCE), the Tropical Ocean and Global Atmosphere (TOGA) program, the World Climate Research Program, and the International Geosphere-Biosphere Program. A steering committee was formed in 1991 (now a permanent secretariat) under the leadership of IFREMER to coordinate French participation in these programs. The other organizations represented include:

CNES	National Space Studies Center (*Centre National d'Etudes Spatiales*)
CNRS	National Scientific Research Center (*Centre National de la Recherche Scientifique*)
ORSTOM	French Scientific Research Institute for Cooperative Development (*Institut Français de*

	Recherche Scientifique pour le dévelopement en coopération)
TAAF	French Southern Lands and Antarctic (*Terres Australes et Antarctiques Françaises*)
SHOM	Navy Hydrographic and Oceanographic Service (*Service Hydrographique et Océanographique de la Marine*)
Météo-France	French Meteorological Office.

Marine Geosciences Department

The Marine Geosciences Department is organized into three laboratories (Lithosphere, Accretion-Hydrothermalism, and Sedimentary Environment), a geotechnical support group, and a management group. In addition to research, this department is actively involved in teaching through groups such as GDR-GEDO (Genesis Research Group and Ocean Dynamics—Groupement de Recherche Genèse et Dynamique des Océan) and the Erasmus "Mercator" marine geosciences network.

The Lithosphere and Accretion-Hydrothermalism Laboratories are actively involved in several major international projects studying oceanic ridge processes. These include FARA (France/U.S.), STARMER (France/Japan), and InterRIDGE (numerous). The FARA/SIGMA campaign was a morphological and geophysical study of the Mid-Atlantic Ridge from the Azores to 33°N; the 1992 FARANAUT campaign was a detailed study of hydrothermalism along the ridge at about 15°N using the manned submersible *Nautile*. The 1987-1991 STARMER project included four surface ship and two submersible campaigns to study the ridge of the North-Fiji basin.

The Sedimentary Environment Laboratory is currently concentrating its efforts on the quantitative study of sediment energy and mass transfers and the circulation of fluids in sediments. Recent areas studied include the China Sea (BOHAI campaign), the Rhodanian slope (TRANSRHO campaign), Flanders Bank, Guadalope, and the western coast of South America.

Deep-Sea Environment and Associated Biotechnologies Department

The Deep-Sea Environment and Associated Biotechnologies Department is active in several international programs, including:

JGOFS	Joint Global Ocean Flux Studies - study of the biochemical processes in the lower ocean depths and the flux of matter in the water-sediment interface
HERO	Hydrothermic Ecosystem Research Observatory (part of the U.S./French FARA program) - study of the temporal variations of organic populations living around deep hydrothermal vents
GUAYNAUT	French/Mexican study of bacterial populations at hydrothermic vents sites in the Gulf of California.

The Biotechnology Laboratory is focusing its attention on some very interesting bacteria collected from hydrothermal vents. Specific current research includes the study of archaebacterial (sic, but I think it should be "archeobacterial") sulfothermophilia, thermostable enzymes, and some unique polysaccharides produced by these bacteria.

Physical and Space Oceanography Department

A new Space Oceanography "Department" was formed in 1991 to analyze data from the ERS-1 satellite in cooperation with CERSAT, the European Space Agency's Center for the Archiving, Processing, and Distribution of Data in Non-Real Time from the ERS-1 satellite (Centre pour l'Archivage, le Traitement et la Diffusion en Temps Différé des Données du Satellite ERS1). Also in 1991, a new Ocean Physics Laboratory (LPO) was formed in partnership with CNRS and UBO

(University of Western Brittany, Université de Bretagne Occidentale), principally to support the World Ocean Circulation Experiment (WOCE).

The Ocean Physics Laboratory's aim is to observe and understand ocean circulation from mesoscale (50 km) to global scale. This is a combined group of scientists who actually work for IFREMER and CNRS. It is headed by Dr. Alan Colin de Verdiere and has about 30 scientists at the IFREMER site and another dozen at the Universite de Bretagne Occidentale. The laboratory's first campaign (ROMANCHE1) in support of WOCE in 1991 precisely mapped fracture zones across the Mid-Atlantic Ridge through which Antarctic waters from the Western Atlantic Basin flow into the Eastern Atlantic Basin. The 1992 campaign (ROMANCHE2) deployed current sensors to evaluate the flow through these fractures over the next two years. Dr. Kevin Speer of the Laboratory is experienced in interpreting the results of water density profiles acquired in these surveys, and he uses these techniques as well (in collaborative work with the Institut fur Meereskunde Kiel) in the South Atlantic Ocean.

In 1991/1992 under a European Community MAST project with Germany, the laboratory explored the use to acoustic tomography to study winter convection in the Mediterranean Gulf of Lions (near Marseilles). The laboratory plans to use acoustic tomography again in 1994 to study the marginal flux in Equatorial Africa in support of WOCE. Dr. Desaubies is continuing his work using this French system (using mostly U.S. components to date). This is a powerful technique whose development was originally fostered by ONR; it is now used both in Brest and at the Institut fur Meereskunde in Kiel. He convened the Second International Symposium on Global Acoustic Monitoring of the Ocean in Brest in June 1993, and the broad list of attendees attests to international interest in this technology.

One of the first tasks of the Space Oceanography Department was to help the European Space Agency validate the data coming from the ERS-1 satellite. The Norwegian Sea campaign (RENE 91) provided in situ wind and wave measurements, which the department processed and compared with simultaneous radar data from ERS-1. The department has also begun a study of sea ice using scatterometer data from the satellite. These data are normally used to determine wind speed, but they also have been shown to be sensitive to ice roughness. Dr. Alain Cavanie is using the ERS-1 scatterometer data to provide an atlas of polar sea ice for the duration of the flight.

This is an interesting development because the sensor has a higher signal-to-noise ratio than does SSM/I data, so it might provide much better resolution in the data set. It is almost as good as the SSM/I data for ice edge discrimination. For this they use a unique algorithm based on the azimuthal isotropy of scattered electromagnetic waves. However, in addition, the data exhibit many significant features within the ice cover. Especially apparent are areas of rougher ice. These areas move with the known general tendency of arctic circulation. This technique potentially could provide motion data every three days for the whole Arctic, as opposed to the month required to get adequate SAR coverage. On the other hand, this would result in some loss of spatial detail.

Dr. Robert Ezraty in this group is working with the ERS-1 Along Track passive microwave (ATSR) system that is similar to SSM/I but has fewer channels. He is analyzing the data for discrimination of ice types. They feel that the two sensors used in collaboration will lead to better type discrimination and motion information. Finally, the department is using SPOT satellite imagery for quantitative analyses of algae fields, evaluation of potential aquaculture sites, pollution monitoring, and mapping of superficial sediments.

The Space Oceanography Department at Brest is headed by a new director, Dr. Kristina Katsaros, who is an air-sea interaction expert and longtime ONR contractor from the University of Washington. The department has 10 scientists and an equal number of support personnel. In the remote sensing work, they are using SSM/I data to improve monitoring of severe storms (although not in real time, because of access issues). The department is also involved in air-sea fluxes in the French SEMAPHORE Program. A recent paper by Dr. Katsaros (with Dr. Mark Donelan, Canada Centre for Inland Waters) on flux observations from the swath ship during the Surface Wave Dynamics Experiment (SWADE) is in press for the *Journal of Marine Systems*. Dr. Katsaros also is co-convenor of the Second International Conference on Air-Sea Interactions and Meteorology and Oceanography of the

Coastal Zone to be held in Lisbon in the fall of 1994. This is a follow up of a large meeting on the same subject in Den Haag in 1982. The meeting has American Meteorological Society support, but Dr. Katsaros is looking for additional financial assistance.

Environment and Coastal Management Directorate

Eleven of IFREMER's fifteen coastal stations work principally for the Environment and Coastal Management Directorate. These eleven are soon to be officially designated "Coastal Observatories," with specific missions to gather, validate, manage, and interpret data concerning the coastal environment and the adjacent land area. The French government inaugurated a National Coastal Oceanographic Program (PNOC, *Programme National d'Oceanographie Côtière*) in 1991. It is run jointly by IFREMER and the National Institute of Sciences of the Universe (*INSU, Institut National des Sciences de l'Univers*).

The directorate's major research themes include:

- ecotoxicology, principally the effects of organophosphorescent pesticides, carbamates, polychlorobiphenyls, and polyaromatic hydrocarbons on marine organisms;
- toxicity of visible light on the bacteria E. Coli in sea water;
- the impact of shellfish farming on the ecosystem, principally oxygen levels and water quality (OXYTHAU Program);
- modeling water quality in the Loire estuary;
- eutrophic coastal environment (i.e., rich in nutrients but frequently seasonally deficient in oxygen) (EUPHORBE Project);
- flux of contaminants in coastal sediments;
- National Toxic Algae Efflorescence Program; and
- National Program for Coastal Oceanography, seeking to (1) determine the role of coastal ecosystems in the larger biochemical cycles of the oceans, and (2) reconcile environmental quality with resource management.

The directorate operates the following coastal monitoring networks:

- RNO (National Monitoring Network for the Quality of the Sea Environment, *Réseau National d'Observation de la Qualité du Milieu Marin*)
- REMI (Microbiological Network, *Réseau Microbiologique*)
- REPHY (Phytoplanktonic Network, *Réseau Phytoplanctonique*)
- RAVEL (Automated Network for Monitoring the Coastal Environment, *Réseau Automatisé de Veille pour l'Environnement Littoral*) (inaugurated in 1991).

Engineering, Technology, and Data Processing Directorate

Engineering Sciences
- Materials
  - MAST: Materials in the Deep Sea (MADS)
  - COMAS (European Community project—Composite Materials for Structures and Components)
- Underwater Acoustics
  - MAST: Acoustic Imaging Development (ACID)
- Underwater Robotics
  - MAST: Advanced Systems Research for Autonomous Underwater Vehicles (AUV)
  - Abyssal Survey Vehicle (ASV)
- Oceanographic Sensors
- Naval Construction
- Underwater Intervention
- Oceanographic Instrumentation
- Fisheries and Aquaculture Technologies

DISCUSSION AND RECOMMENDATION

This short overview provides only an introduction to the complex organization of civilian oceanographic R&D in France. IFREMER has an increasing emphasis on international work, both within Europe as well as global climate issues, and further assessment of the developments is recommended. Review of the new coastal monitoring program called RAVEL, in particular, is warranted.

Contacts

IFREMER Headquarters
President-Director General Pierre Papon
66 Avenue D'Iena,
75116 Paris, France
Phone: +33 1 47 23 55 28
Fax: +33 1 47 23 02 79

Institut Francais de Recherche pour l'Exploitation de la Mer (IFREMER), Centre de Brest
Dr. Kristina B. Katsaros
Head, Departement d'Oceanographie Spatiale
BP-70 Plouzane/Brest
France, F-29280
Phone: +33 98 22 43 16
Fax: +33 98 22 45 33
Omnet: K.KATSAROS
E-mail: katsaros@ifremer.fr

Dr. Alain Colin de Verdiere
Head, Laboratoire de Physique des Oceans (LPO)
BP 70 Plouzane/Brest
France, F-29280
Phone: +33 98 22 40 40
Fax: +33 98 22 44 96
Omnet: A.COLINDV

Dr. Yves Desaubies
(same address)
Omnet: Y.DESAUBIES

Dr. Kevin Speer
(same address)
E-mail: speer@ifremer.fr

Policy

French Perspectives on European Scientific Research

by Christine Glenday, Head of the National Science Foundation European Office

KEYWORDS: "European dimension"; scientific cooperation; economic problems; European Science Foundation; French National Committee for Scientific Research

EXECUTIVE SUMMARY

The French National Committee for Scientific Research is an elected body of distinguished scientists who are responsible for evaluating French scientific institutes on a regular basis. The Committee met in full session in Strasbourg, 22-23 April 1993, to discuss "European Perspectives on Scientif Research." The theme of the meeting, which was opened by France's new Minister for Higher Education and Research, Francois Fillon, was selected to sensitize the French research community to "think European," as well as to discuss the growing role and influence of European Community (EC) funding in science. In addition to French scientists, representatives from other scientific organizations in Europe attended, in particular from Eastern Europe.

THE MEETING

The French National Committee for Scientific Research meets on a regular basis to evaluate French research institutes, under the auspices of the National Center for Scientific Research (CNRS). Although the various disciplinary subcommittees meet at least twice a year, the entire National Committee has met only twice in full session. The objective of the full sessions is to bring together the Committee to discuss issues of par-ticular importance to the scientific community at large. The theme of the 1990 meeting was

"Multidisciplinary Research;" in 1993, the theme was "European Perspectives on Scientific Research."

According to CNRS officials, the 1993 theme of European research integration was selected in part to educate the French research community to "think European." In addition, the meeting provided a forum to discuss the increasing role of the European Community in funding science programs. Last but not least, the meeting gave the Director-General of CNRS, Francois Kourilsky, the political opportunity to demonstrate the "European orientation" of CNRS to representatives of France's recently elected government.

The meeting was attended by more then 700 people. It was opened by Francois Fillon, who was making his first public appearance since being appointed the new Minister for Research and Higher Education on April 1, 1993. He reassured the audience that the new government will continue to give high priority to research. At the same time, he indicated that all sectors of the economy will have to share the financial burden of the government's new plans to deal with the country's current economic problems. He stated his strong support for the "European dimension" of science, through maintenance of large facilities such as CERN, as well as through participation in the European Science Foundation. He cited health (AIDS) and the environment as two areas in which cooperation was especially important. He referred several times to the importance of greater scientific cooperation with Eastern Europe, citing the successful programs involving "twinning" of French and Eastern European laboratories. Widely known for his "anti-Maastricht" political views, Fillon was fairly outspoken in his references to the European Community.

While acknowledging the importance of the EC's Fourth Framework Program for selected research areas, he pointed out that the EC's ultimate objective is to maintain the competitiveness of European industry, not to the support of basic science. He also criticized the excessively complicated EC bureaucratic and administrative procedures, which, in his view, were hindering its effectiveness. While acknowledging the "crucial" role of the EC for the European economy, he felt that national governments should take a greater role in pressuring for "more simplified" procedures for participation in EC programs, in order to "re-establish confidence" in EC itself. He also emphasized that strong national initiatives in science were "indispensable," regardless of the growing scope of EC activities.

Presentations were also made by Francois Kourilsky, Director General of CNRS, as well as by Carlo Rubbia, Director General of CERN, and by George Charpak, recent Nobel Prize winner in Physics. While emphasizing the importance of European cooperation in science, Kourilsky referred to "difficulties" with the EC's Third Framework Program. Rubbia gave a presentation on CERN, describing it as a "model" European research organization.

ROUND TABLE DISCUSSIONS

Six round table discussions were held in parallel sessions on the following topics:

- Modes of Integration in European Research,
- Laboratories and Resources in Europe,
- Communications, Publications, and Languages,
- Evaluation of Research in Europe,
- Careers and Mobility, and
- International Scientific Relations between Europe and the World.

The sixth Round Table, "International Scientific Relations between Europe and the World," was of special interest, since relations with Eastern Europe were discussed at some length. Dr. Wlodzimierz Zagorski, Director of Biochemistry and Biophysics, Polish Academy of Sciences, described the success of the newly established joint French-Polish Plant Biotechnology Center in Warsaw (which he also directs).

Dr. Robert Klapisch, Advisor to Carlo Rubbia and former Director of Research at CERN, stated that there are 50 Russian researchers at CERN on a permanent basis, and that one Russian is on the CERN Senior Council. He also reviewed the history of Rubbia's effort, supported by President Mitterrand, to create an International Fund for Basic Research to benefit Russian researchers. This fund would support research projects in Russia itself, thereby permitting scientists to remain in their

own laboratories rather than emigrating. Although the initial idea was to avoid government structures, eventually the French Ministry of Research decided that the Foundation should be under the auspices of the EC. This is the background to the establishment of the International Association for the Promotion of Collaboration with Scientists from the Independent States of the Former Soviet Union. Proposed by the EC, this Association is to be a separate Belgian legal entity, open to membership from both government and private organizations worldwide. It is yet to be operational, although it is to have a budget of 20 million ECU in 1993.

Dr. Rainer Gerold, Director for International R&D Cooperation in the EC's DG-XII (Science, Research and Development), acknowledged the slow pace of certain of the EC's efforts, due in part to internal "administrative blocks." He also referred to delays in the operation of the International Science and Technology Center (ISTC) in Moscow, for which the EC also contributes funds. In his view, this is due in part to Russian unwillingness to open certain of its laboratories, as well as to political problems caused by the general chaos in the Parliament.

OTHER PARTICIPANTS

Dr. Yevhen Bersheda, Science Advisor to President Kravchuk of Ukraine (as of January 1993), challenged the excessive focus in Europe on scientific problems in Russia, at the expense of Ukraine and other former Soviet republics.

Aside from Bersheda, several other representatives from Eastern Europe attended the conference, reflecting the strong connections maintained by CNRS with its Eastern European counterparts. Among those attending were Dr. Anatoly Shpak, newly elected Scientific Secretary of the Ukrainian Academy of Sciences; Dr. Niederle, Director, International Affairs, Czech Academy of Sciences; and Dr. Dusan Berek, Director of International Affairs, Slovak Academy of Sciences. Dr. Leonid Glukharev, a professor of Economics from Moscow University, also attended in his capacity as Director of the Center of Problems of European Integration (although his main interest appeared to be more philosophical—"the renaissance of the European thought"). In addition, Brigitte Godelier, CNRS Representative in Moscow, attended the meeting.

COMMENTS

Although much of the discussion was very broad, the meeting provided an excellent opportunity to make contacts with many French and other European scientists and government administrators, as well as to observe French concerns with the growing scientific influence of the EC.

French Science and Technology Cooperation With Eastern Europe and the Former Soviet Union

by Christine Glenday, Head, National Science Foundation European Office

KEYWORDS: MICECO; CNRS; INRIA; laboratory twinning; joint agreements

EXECUTIVE SUMMARY

In addition to a longstanding history of scientific cooperation with the former Soviet Union and Eastern Europe dating from the mid-1960s, the French government significantly expanded its efforts in 1990 through the establishment of a special interministerial committee called MICECO. In coordination with the French Ministry of Research, the government supports a wide variety of mechanisms for cooperation, including fellowships, laboratory twinnings, and conference support. Both the National Center for Scientific Research (CNRS) and the National Institute for Computer Science and Automation (INRIA) support substantial collaboration efforts with Eastern Europe and the former Soviet Union. In addition, the Ministry of Defense has a special fund aimed at benefiting

French industry by providing opportunities for collaboration with former Soviet researchers in "dual technologies."

INTRODUCTION

France has a longstanding history of cooperation in science and technology with the former Soviet Union, following the signing of a formal agreement between the two countries in 1966. In April 1990, the French government launched a special initiative for scientific cooperation with Central and Eastern Europe, including the former Soviet Union, to be coordinated through an independent interministerial organization known as MICECO. Together with the Ministry of Foreign Affairs (MAE), from which it receives its funds, MICECO determines overall government policy and provides funding for a variety of programs managed by the Ministry for Research (MRE), the Ministry for National Education (MNE) and individual laboratories. MICECO's total budget for 1993 is 450 million FF ($85 million), with about 45 million FF ($8.5 million) specifically earmarked for Russia.

MINISTRY FOR RESEARCH

The Ministry for Research (MRE) is a principal source of funds for cooperation in civil research and development, specifically fundamental research. In July 1992, Hubert Curien, former Minister for Research and Space, and Boris Saltykov, Russian Minister for Science, signed an agreement for enhanced collaboration in science and technology with emphasis on industrial technology. Specific mechanisms for collaboration listed in the agreement are:

- scientific exchanges,
- long-term visits,
- conferences,
- twinning of laboratories, and
- development of joint institutions to facilitate technology transfer and information exchanges.

In addition to funds received from MICECO, the MRE has allocated approximately 35 million FF ($6.6 million) in 1993 for collaboration with Eastern Europe and the former Soviet Union.

The MRE supports a variety of programs, the most important of which is a program to support fellowships for senior researchers and postdocs. Fellowships are provided for a period of 1 to 6 months for senior researchers and 6 to 18 months for postdoctoral researchers. Candidates are nominated by French laboratories or other receiving organizations; they are selected by a panel that also includes representatives from MICECO, the Ministry of Foreign Affairs and the Ministry of National Education. Since 1990, more than 900 fellowships have been awarded, with approximately one-third of the successful applicants from Russia. (Note: The Ministry of National Education also manages a small program of support for visits of 3 to 6 months for postdoctoral researchers to come to France).

The BRITEST Program was set up in 1991 as a way to allow researchers from the East to work in French industrial laboratories, with co-financing from the company involved and from MRE and MICECO. In 1992, 24 awards were made. Companies involved in the program are Saint-Gobain, Electricite de France (EDF), Thomson, Genset, Wellcome Laboratories, and Orsan Laboratories.

The ACCESS Program assists researchers from the East to attend scholarly meetings in France, based on nominations by French conference organizers. In 1992, more than 812 Eastern European researchers were supported to attend 159 conferences.

The PARCECO Program pays for French researchers to attend meetings or summer schools organized, usually jointly, by French organizations and a local organization in Eastern Europe. In 1992, 407 researchers were supported to attend 28 summer schools.

A program of "laboratory twinnings" has also been highly successful; more than 21 twinnings were supported in 1992. The purpose of such twinnings is to establish long-term partnerships through exchange of researchers and visits of young foreign students preparing for the Ph.D. Examples of such twinnings are: Paris University VI and VII with the St. Petersburg Steklov Institute (for mathematics and theoretical and high-energy physics); Pasteur Institute with the Institute

Puschino outside Moscow (for microbiology); the Ecole Normale Superieure and the Landau Institute of Physics in Moscow; the Center for Low Temperature Research (CRTB/Grenoble) with the Kapitsa Institute, Moscow (for solid state physics); and the Ecole de Mines, Paris, with the Lomonosov University, Moscow (for environmental studies).

OTHER GOVERNMENT ORGANIZATIONS

National Center for Scientific Research (CNRS)

The CNRS has had long-standing agreements for collaboration in fundamental research with the former Soviet Academy of Sciences as well as with other Academies of Science in Eastern Europe. The CNRS supports exchanges of researchers as well as laboratory twinnings. In addition to joint projects supported by CNRS technical divisions, the CNRS Division of International Programs has a current allocation of 4.2 million FF ($800,000) for the support of collaborative programs (with researchers travelling in both directions), including joint seminars, with Eastern Europe and the former Soviet Union. Since 1991, the CNRS has had a full-time representative in Moscow, who has become an important information resource on current research conditions in Russia.

CNRS is planning to sign an agreement jointly with the Ukrainian Academy of Sciences, the Ukrainian Ministry of Education, and the State Committee for Science and Technology in the spring of 1993. Fields selected for the initial phase of the agreement (chosen by the Ukrainian side) are chemistry, oceanography, and environmental issues related to Chernobyl. In addition, Ukraine has asked CNRS for assistance in training "scientific administrators".

Aside from Russia (and shortly Ukraine), the CNRS does not have immediate plans to sign agreements with any other former Soviet republic. However, the CNRS does plan to give some support to individual astrophysicists and particle physicists in Armenia.

The CNRS has also had a long-standing agreement with the Polish Academy of Sciences, most recently renewed in 1992. However, CNRS has insisted that applications on the Polish side also be open to the Polish university community. The Director of CNRS, Francois Kourilsky, recently visited Poland to sign an agreement with both the Polish Academy of Sciences and the Polish State Committee for Scientific Research (KBN) to establish a Franco-Polish Research Center for Plant Biotechnology.

National Institute for Computer Science and Automation (INRIA)

INRIA also has had a long history of collaboration with Russia, dating from the mid-1960s. As in the case of CNRS, INRIA supports the exchange of researchers to work on specific joint projects in areas of computer science and applied mathematics. In February 1992, INRIA signed an agreement with Moscow State University (Lomonosov University) for collaboration, specifically in the fields of systems theory and numerical methods. Modes of collaboration include: exchange of postdoctoral researchers, exchange of scientific publications, organization of joint seminars, and specific joint research projects.

In December 1993, INRIA signed an additional agreement with Moscow State University for the creation of a Franco-Russian Center for Applied Mathematics and Informatics, to be located at Moscow State University. INRIA will provide a substantial number of workstations directly to the Center to facilitate work on joint projects.

National Institute for Health and Medical Research (INSERM) and National Institute for Agricultural Research (INRA)

Both of these institutes also support the exchange of researchers on a more modest scale than the CNRS.

Ministry of Defense

In April 1992, former Minister Curien and Minister of Defense Joxe announced the establishment of a special program to benefit French industry by providing opportunities for cooperative research with the former Soviet Union in "dual technologies"—those technologies with a potential for both civilian and military use. Cooperative efforts are concentrated on purchases of technology, agreements to conduct research, and invitations to researchers. Topics of particular

interest to French industry in this effort are: aerospace, materials, metallurgy, hypersonic propulsion, and optics. In this program, the Ministry of Defense acts as an intermediary between French industry and former Soviet research institutes by advertising in France opportunities for collaboration in specific technologies. In 1992, the program was funded at the 50 million FF ((\$9.4 million) level. In 1993, the expected budget is 60 million FF (\$11.3 million).

U.K. Programs for Science and Technology Cooperation With Eastern Europe and the Former Soviet Union

by Christine Glenday, Head, National Science Foundation Europe Office

KEYWORDS: The Royal Society; collaborative programs; memorandum of understanding; Know How Fund; SERC

SUMMARY

Since 1992, British Government efforts in science and technology (S&T) cooperation with Eastern Europe and the former Soviet Union (FSU) have been concentrated on providing additional funds to the Royal Society and to the "Know How Fund." The Royal Society has a long history, dating from the 1950s, of scientific exchanges with the former USSR Academy of Science, as well as with other Academies in Eastern Europe. The Know How Fund was created in 1990 to support the transfer of British technical and managerial expertise to promote economic reform in the FSU and other Eastern European countries, in collaboration with the British private sector. It is jointly managed by the Foreign and Commonwealth Office and the Department of Trade and Industry. In addition, the Science and Engineering Research Council (SERC) and the Natural Environment Research Council, although not targeting special funds for EE/FSU research, have a variety of formal and informal links for research collaboration with EE/FSU scientists.

S&T PROGRAMS OF THE ROYAL SOCIETY

In response to demands by the British scientific community to help FSU scientists, in September 1991 the Cabinet Office asked the Royal Society to produce a report on the state of science in the former Soviet Union. This was urgently needed to assess the need for increased British government efforts for S&T collaboration. This report, "Academies of Sciences in the Constituent Republics of the Former Soviet Union: A Current Appraisal," was completed in January 1992. It was based on extensive material supplied by British scientists who had recently visited the FSU.

As a result of recommendations of this study, the British government allocated 2 million pounds (\$3.1 million) in May 1992 for increased S&T programs in the FSU over a three-year period. These funds came from the combined resources of the Office of Science and Technology (OST) and the Department of Trade and Industry. In 1992, the Royal Society received 550,000 pounds (\$864,000); another 120,000 pounds (\$188,000) was allocated to the Know How Fund for the "management of science."

Previously, the Royal Society spent about 300,000 pounds (\$471,000) annually on exchange programs with the former USSR Academy of Sciences. With the infusion of new government funds in 1992, this amount was increased to 850,000 pounds (\$1.3 million).

In May 1992, the Royal Society signed an agreement with the Russian Academy of Sciences. Memoranda of Understanding have also been signed with Belarus, Estonia, Georgia, Latvia, Lithuania, and Ukraine. Discussions have also taken place with science officials from Kazakhstan regarding future cooperation.

Types of activities currently supported by the Royal Society include:

- exchange visits of two weeks to three months between British and FSU researchers,
- postdoctoral fellowships in the U.K. for FSU candidates under age 40,
- invitations to senior FSU researchers to visit the U.K. for up to three months ("Kapitza Fellowships"),
- joint research projects, up to three years in duration,
- joint symposia, and
- invitations to FSU researchers to attend international conferences held in the U.K.

The Royal Society also maintains an extensive computerized database on FSU research institutes based on reports of visiting British researchers, scientific journals, and published directories.

In addition, following the example of the French National Center for Scientific Research (CNRS) in 1991, the Royal Society has supported a full-time representative in Moscow since August 1992 to serve as an information officer and to promote collaboration. (Note: the British Council, which has a large staff in Moscow, also plans to send a science officer to Moscow, and has recently become involved in promoting scientific collaboration with Ukraine).

THE KNOW HOW FUND

The Know How Fund is a key component of the British Government's efforts to help countries of Eastern Europe and the former Soviet Union move toward economic reform. The first Fund, established for Poland in 1989, was followed by Funds for Hungary (1990), Bulgaria and Romania (1991), and Slovenia, Albania, and the Czech and Slovak Republics (1992).

The Know How Fund for the Former Soviet Union, including Estonia, Latvia, and Lithuania, began in 1990 with a budget of 20 million pounds ($31 million), increased to 50 million pounds ($78 million) in 1991. The Funds are jointly managed by the Foreign and Commonwealth Office and the Department of Trade and Industry to support economic reform through the transfer of technical expertise in collaboration with the British private sector.

In the case of Central and Eastern Europe, the main priorities have been assistance to the financial services sector, cooperation between employment services, advice on the establishment of small businesses, management training, and the training of civil servants and local government officials. The Fund is disbursed mainly in support of projects that include a British private sector contribution to costs.

In the case of the Russian Federation, the Fund operates in four specific sectors:

1. Food Production and Distribution: promote structural improvement in Russia's food production, processing, and distribution chain, through support for programs to introduce the principles of private enterprise and response to consumer demand.

2. Small Business Creation and Employment: provide assistance in the creation of small businesses through advising on effective business practices and retraining of the workforce.

3. Energy: support cost-effective exploitation of oil and gas, and introduce energy-efficient practices to emerging business and industry.

4. Financial Services: introduce banking, accountancy, insurance, privatization, and other assistance in industrial restructuring.

Universities, polytechnics, and other higher education or specialized training institutions in Britain may also seek support from the Fund for joint projects with counterpart organizations in the FSU, aimed at strengthening links in one or more of the Fund's four operating sectors. This element of the Know How Fund, called the Training and Academic Links Program, has been managed though the British Council.

The Know How Fund has received additional financing from the British Government's 2 million pound special allocation for S&T for programs aimed at "management of science." These funds

have primarily been for the Training and Academic Links Program.

U.K. RESEARCH COUNCILS

Science and Engineering Research Council (SERC)

SERC maintains several Memoranda and Protocols with FSU scientific institutions, although it does not maintain a separate budget allocation for collaborative research with the FSU. Included among the agreements are:

- Memorandum of Understanding (MOU): between the Daresbury Laboratory and the Russian Academy of Sciences (RAL) Commission on Synchrotron Radiation on the construction of synchrotron radiation sources.
- Protocol between Rutherford Appleton Laboratory and the Joint Institute for Nuclear Research, Dubna, for development and use of pulsed neutron sources in condensed matter research.
- Agreement between SERC and the P.N. Lebedev Institute of Physics, Moscow, for joint research on laser and plasma physics.
- Protocol between SERC and the RAS Mechanical Engineering Research Institute for collaboration in civil engineering.
- MOU between Imperial College, London, and the Moscow Energy Institute on the development and application of autonomous wind diesel systems.
- MOU between Rutherford Appleton Laboratory and the Institute of Space Research (RAS), a high-level agreement under which SERC agreed to design and supply an X-ray telescope (JET-X) to form part of the payload of the Spectrum-X satellite.
- Agreement between the Daresbury Laboratory and the RAL Institute for Molecular Genetics for collaboration in the mechanisms associated with protein instability.

Other Research Councils

The Natural Environment Research Council (NERC) has more than 100 projects with the FSU, primarily with Russia, including association through the Ocean Drilling Program. The Medical Research Council (MRC) has no formal agreements with the FSU, in accordance with its policy to encourage collaboration through informal contacts.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave Blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1993	Multidisciplinary Research Bulletin

4. TITLE AND SUBTITLE

European Science Notes Information Bulletin

5. FUNDING NUMBERS

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Office of Naval Research
European Office
PSC 802 Box 39
FPO AE 09499-0700

8. PERFORMING ORGANIZATION REPORT NUMBER

93-07

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

NAVSO P-3678

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

European Science Notes Information Bulletin describes research being conducted and ideas being developed in Europe and the Middle East as reported by scientists assigned to the Office of Naval Research European Office and guest authors. It is published 6-8 times per year, on an irregular basis.

14. SUBJECT TERMS

Computer Science
Materials
Oceanography
Policy

15. NUMBER OF PAGES

70

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std 239-18
298-102